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Editorial: Where did the virus come from?

Robert Marks

Economics, University of New South Wales, Sydney

Email: robert.marks@gmail.com

The pandemic continues, with the science behind the COVID-19 vaccines taking a bow. There are ongoing enquiries about how the virus emerged, but Edward Holmes, FRSN and NSW Scientist of the Year 2020, tells me that there is absolutely no evidence of an engineered virus. Indeed, he says, the genotype shows all the evidence of a zoonotic origin, although whence and exactly when it first infected people remain unclear.

This issue of the *Journal* contains three refereed papers: one in reference to the late Douglas Adams' (2002) thoughts (the 'puddle theory') on the likelihood of human life — indeed, *any* life — in the universe; one on the Ellesmere meteorite, found in August 1900 in northern NSW, not southern Queensland as erroneously believed; and a paper on self-sensing concrete, by Wengui Li et al.

Indeed, 2020 was the year in which the Society awarded the Warren Prize for the first time, to Dr Simon Devitt, a quantum computer scientist at UTS. The aim of the Prize is to recognize research of national or international significance by Australian engineers and technologists in their early to mid careers. In each case, the research must have originated or have been carried out principally in New South Wales. I look forward to publishing a promised paper from Dr Devitt soon.

A second award in 2020 — the Archibald Ollé Award for Best Paper published in the

Journal — went to the late Dr Ann Moyal FRSN, for her 2017 paper (Moyal, 2017), written to discuss war-time correspondence between Dr Moyal's late husband, Professor José Moyal, erstwhile professor at Macquarie, and P. A. M. Dirac, the preeminent Nobel laureate physicist of his time at Cambridge. Although Dirac was skeptical of Moyal's statistics approach to quantum mechanics, history has vindicated Moyal: the most recent count from Google Scholar for Moyal (1949), a paper that summarised an earlier unpublished paper (that Dirac had persuaded Moyal¹ to delay), is 3798 cites, at a rate of over 13 cites per month, amazing for a quite abstruse paper published over seventy years ago. The Archibald Ollé Award was last presented in 1997.

As well as the three reviewed papers mentioned above, this issue includes a new section, 'Great N.S.W. Inventions,' recording in this issue a presentation made at the November 2020 O.G.M. on the role of two of our Fellows in the amazing development of the virtual elimination of peptic ulcers. Was it an example of synchronicity that Adrian Lee FRSN had found that, far from being germ-free, mammalian stomachs are alive with bacteria that appear to relish the inhospitable environs of the stomach and gut at the same time that Barry Marshall and Robin Warren isolated the bacterium now

¹ Moyal had recently escaped from occupied France, and had been directed to work at de Havilland's by C. P. Snow, then in charge of Scientific Manpower.

known as *Helicobacter pylori* from human stomachs, and suspected that it was implicated in peptic ulcers? Previously, peptic ulcers were believed to be caused by excess stomach acid, or spicy food.²

Adrian Lee and Thomas Borody FRSN provided the means for establishing that Marshall and Warren were right, using the methodology of the Koch postulates. Borody and Lee developed a therapy to kill the bacteria *in vivo*, a necessary step in the proof. Marshall and Warren shared the Nobel Prize in Physiology in 2005 for their discovery. I agree with Peter Baume FRSN and others that both Adrian Lee and Thomas Borody deserved to share in the Nobel glory.

The issue also includes the seven presentations by the participants in last November's Four Academies Forum on "After COVID-19: Creating the Best of Times from the Worst of Times," as well as a discussion, the Governor's opening address, and the rapporteur's summing-up. Will the government take their advice after the pandemic? This remains to be seen.

The issue also includes three PhD abstracts.

Since 2013 the *Journal* has been fortunate to have had 118 reviewers and helpers in the process of processing papers. Such people have not been publicly thanked for some years, but we acknowledge them explicitly in this issue, with their names and affiliations listed below.³ This is my eleventh issue;

² See Graham and Dore (2016) for a comprehensive discussion of this.

³ We could not determine the affiliations of three people: Peter Ackland, Xanthe Lam, and Alan Palmer. If you have information on any of these, or any other person on the list, please let us know: we can amend the on-line documents. Sadly, Brian Spies FRSN (1949–2020) has died since his seminal contribution to the 2016 Forum (Spies, 2017).

Michael Burton (2013–2015) and Donald Hector (earlier) were the editors immediately before me.

This year marks the two-hundredth anniversary of the Philosophical Society of Australasia, which is the direct ancestor of today's Royal Society of New South Wales. Given this timely anniversary, I am sad to note that the Federal Government is refusing to fund the National Archives of Australia adequately; the Archives, under the Attorney-General's Department, have been reduced to appealing for donations from Australian citizens, an unwelcome version of crowdfunding. Meanwhile, other national institutions, such as the Australian War Memorial, are being more than adequately funded by the Federal Government. To celebrate our two-hundredth anniversary, the Royal Society will present the exhibition, 'The Royal Society of New South Wales. Nexus: Origins, Ideas, Advances, Impacts, 1821–2021' at the State Library of NSW from late June 2021. A personal note: one of my oldest friends, John C. H. Spence ForMemRS, died aged 75 in June 2021; he published a paper here in 2019.

Housekeeping

I wish to thank Jason Antony for his excellent work at formatting this issue of the *Journal*, while at the same time editing the Society's *Bulletin*. The Editorial Board has provided excellent editorial support, as always. See the inside front cover for the Board's membership.

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Thank you

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Peter Ackland	Andrew Blakers <i>Australian National University</i>	Eric Colhoun <i>University of Newcastle</i>
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JOURNAL & PROCEEDINGS OF THE ROYAL SOCIETY OF NEW SOUTH WALES
 Marks — Editorial: Where did the virus come from?

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University of Otago

Heinz Hora
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Suzanne Hand
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Baker Heart & Diabetes Institute

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Argonne National Laboratory

Ghil'ad Zuckermann
University of Adelaide

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The trouble with “puddle thinking: A user’s guide to the Anthropic Principle

Geraint F. Lewis¹ and Luke A. Barnes²

¹Sydney Institute for Astronomy, The University of Sydney, Australia

²Western Sydney University, Australia

Email: geraint.lewis@sydney.edu.au

Abstract

Are some cosmologists trying to return human beings to the centre of the cosmos? In the view of some critics, the so-called “Anthropic Principle” is a desperate attempt to salvage a scrap of dignity for our species after a few centuries of demotion at the hands of science. It is all things archaic and backwards — teleology, theology, religion, anthropocentrism — trying to sneak back in scientific camouflage. We argue that this is a mistake. The anthropic principle is not mere human arrogance, nor is it religion in disguise. It is a necessary part of the science of the universe.

Introduction

In the 1930s, the Nobel-Prize-winning physicist Paul Dirac was pondering strange coincidences between the fundamental numbers of nature (Dirac, 1938). He worked out the ratio of the *electromagnetic* force to the *gravitational* force between an electron and proton in an atom and got a huge number: 10^{40} . He also worked out the ratio of the *age of the universe* to the time it takes for *electrons to orbit* in an atom and got another huge number: 10^{39} . Curiously, these numbers are similar. Maybe it’s just a coincidence, or maybe — Dirac thought — it’s a clue to deeper laws of nature.

In the early 1960s, astronomer Robert Dicke compellingly argued that it was *neither* (Dicke, 1961). He realised that there is something usual about Dirac’s relation, something hiding inside one of the quantities: *us*. Like all of us, the universe is getting older. So, the *age of the universe* in Dirac’s second ratio isn’t a fundamental constant. It’s the time between the beginning of the universe and *us, here, now, today*. Any

account of the coincidence must consider how the Universe makes beings that are capable of measuring its age.

Dicke realised that we cannot be living at any random time in the universe. Firstly, in its youth, the cosmos was a featureless sea of the simplest atoms: hydrogen and helium. The elements needed for life — from the carbon that provides the backbone for organic molecules, to the calcium that provides the backbone for our backbones — are formed in nuclear reactions at the hearts of stars and are recycled by stellar winds and supernova explosions into planets, and ultimately life. Secondly, in the dim and distant future, most of the stars have died, and the energy to sustain life becomes rare. The building blocks for planets and people are entombed in the ever-cooling cores of stars or inside black holes. Life, in this distant future universe, would be precarious, and probably much rarer than today.

Putting these two facts together, *given that life exists at all*, we should not be surprised to find that when we measure the

age of the universe, we get an answer that is greater than (but not too much greater than) the lifetime of a star. When we express this relation in terms of the fundamental constants (using a simple model for stars), we get Dirac's coincidence.

It is a mistake to think that Dicke is saying that our time in the universe is "special," that "our Universe stands at a 'golden interval', neither too young nor too old, but just right."¹ Rather, Dicke is employing a basic principle of the scientific method: what you observe depends on what you are looking *at* **and** what you are looking *with*. When it comes to the universe, we are not Dr Frankenstein, setting up our scientific equipment when and where we please. We are the monster: we have woken up in the middle of the contraption that made us and are trying to understand how it all works.

Looking through our eyes

The natural question for cosmologists and physicists to ask next is: what else about our universe could be explained in this way? What combination of fundamental laws and our necessarily limited perspective best accounts for our observations of the universe?

In search of the answer, physicists delved into the deepest properties of nature, including the masses of the fundamental particles and the strengths of the fundamental forces. By considering other hypothetical universes, it was found that slight deviations in these fundamental properties often result in dead and sterile universes that lack the complexity necessary for life (for a recent review, see Adams 2019). This is known as the cosmo-

logical fine-tuning problem: the ability of the fundamental laws of our universe to provide the right conditions for life of any conceivable kind is a seemingly very rare talent indeed. As summarised in our recent book *A Fortunate Universe: Life in a finely tuned cosmos* (2016), many small changes have disastrous effects. If the strong force were slightly weaker or the fundamental masses slightly heavier, the periodic table would not exist. If gravity were weaker or the universe expanded too fast, matter would not form into stars to forge elements, or indeed make any structure at all. Such a universe would be too simple, too short-lived, or too empty to ever host life.

Note well: we have arrived here without any assumptions about human specialness or religious jiggery-pokery. Saying that the universe is "fine-tuned for life" is not to say that it has a fine-tuner! It is only to say that there is something rare about the physical parameters that life requires. We're just doing science. Fine-tuning for life has been studied by physicists for decades, using the best theoretical tools available, and published in peer-reviewed journals.

Other life-forms and other universes

Wait a minute, we hear you say. How can you make such sweeping statements about life and universes when we don't have a good definition of what life is, and we don't know what other universes are even possible?

For the first objection, we reply that the fine-tuning for life is really the fine-tuning for the complexity required by life. We don't assume that another possible way the universe could have been is life-prohibiting

¹ "Anthropic arrogance," David P. Barash, Aeon: <https://aeon.co/essays/why-a-human-centred-universe-is-not-a-humane-one>

because we couldn't live there. The kind of life-prohibiting disasters that await in other universes are the non-existence of chemistry, or indeed, any way at all to stick two particles together. Or a universe that ends before anything could stick together. Or a universe that expands so fast that no two things have any chance of sticking together. This is a long way from the debate over whether a virus is alive.

But how do we know that these other universes are possible? As the ANU's Charley Lineweaver has pointed out to us, "There is no fine-tuning if there are no knobs." But think about that claim for a moment. These other, life-prohibiting universes are perfectly mathematically consistent. So who took the knobs away? A deeper physical law? Great! What is it? And why is it a physical law that allows life forms, rather than one that doesn't? In the words of Carr and Rees (1979), "even if all apparently anthropic coincidences could be explained [by some presently unformulated physical theory], it would still be remarkable that the relationships dictated by physical theories happened also to be those propitious for life."

Perhaps something deeper than the laws of nature took the knobs away, like a metaphysical principle? Great! What is it? And why is it a metaphysical principle that allows life forms, rather than one that doesn't? And what a stunning comeback for armchair philosophy! Scientists have been toiling for centuries, learning about the universe by actually measuring it. But all this time, we could have been deriving the mass of the electron from some *a priori* philosophical principle with a deep affinity for the number 4.185463×10^{-23} (the electron mass in Planck units).

Whence the Anthropic Principle?

The term "anthropic principle" comes from a presentation by astrophysicist Brandon Carter in 1973, at a celebration of Copernicus's 500th birthday. Building upon the insights of Dicke and others, Carter argued that our position in time and space must be taken into account in our scientific theorising about the world, noting that:

Although our situation is not necessarily *central*, it is inevitably privileged to some extent.

Carter is echoing Dicke's insight: there are times and places in our universe where life is overwhelmingly more likely to exist, and so our perspective on the universe is *necessarily* limited. This is what Carter called the *weak anthropic principle*.

Carter also proposed a *strong anthropic principle*:

The Universe (and hence the fundamental parameters on which it depends) must be as to admit the creation of observers within it at some stage.

This principle is liable to be misunderstood due to the word "must." Its sense here is consequential, as in "there is frost on the ground, so it must be cold outside." We are physical life forms capable of measuring the universe, but not all fundamental laws allow for such things. Carter's strong anthropic principle is *not* proposing that our existence *causes* the universe's fundamental properties, or that any deep metaphysical principle or divine being was involved.

Here's where the confusion starts: others have not followed Carter. In 1986, physicists John Barrow and Frank Tipler published the influential book, *The Cosmological Anthropic Principle*. They brilliantly explained how the overall properties of the cosmos, the details

of the fundamental particles, and the forces that bind them together combine to produce the complexity and energy necessary for life.

But on the anthropic principle, Barrow and Tipler muddled the waters by giving the *same* term a *different* definition. They proposed a weak anthropic principle that combines Carter's strong and weak principle:

The observed values of all physical and cosmological quantities are not equally probable but they take on values restricted by the requirement that there exist sites where carbon-based life can evolve and by the requirement that the Universe be old enough for it to have already done so.

This is Dicke's insight. So far, so good. But Barrow and Tipler proposed a new strong anthropic principle, one that *sounds* similar to Carter's strong principle, except that the word "must" is now given full speculative licence. Perhaps, they say, the universe has a designer, or "observers are necessary to bring the Universe into being." This version of the strong anthropic principle is metaphysical.

So, now we have two versions of the weak anthropic principle and two versions of the strong anthropic principle, those from Carter and those from Barrow and Tipler. Confusion was inevitable.

In addition, Barrow and Tipler added yet more "anthropic principles," such as the Final Anthropic Principle: "Intelligent information-processing must come into existence in the universe, and, once it comes into existence, it will never die out." The dominant form of life over the history of the universe would be some kind of über-

computer, digital consciousnesses enjoying an everlasting virtual reality paradise. This is, to put it mildly, speculative.

Thus, Carter's important and necessary idea has become both associated with disreputable and speculative company. Understandably, many scowl whenever the anthropic principle is mentioned. The feeling is that the anthropic principle is at best tautological and invoking it to explain any feature of our Universe is "the last refuge of the scoundrel." And, at worst, the principle is untestable conjecture.

Are we a puddle in a hole?

The question is: what do we do with the fine-tuning of the universe for life? Does (Carter's) anthropic principle explain why a life-permitting universe exists?

Douglas Adams, in his posthumously published book *The Salmon of Doubt* (2002), famously lampooned the attempt to argue from the features of our environment to any greater cosmic purpose:

This is rather as if you imagine a puddle waking up one morning and thinking, "This is an interesting world I find myself in — an interesting hole I find myself in — fits me rather neatly, doesn't it? In fact it fits me staggeringly well, must have been made to have me in it!" This is such a powerful idea that as the sun rises in the sky and the air heats up and as, gradually, the puddle gets smaller and smaller, frantically hanging on to the notion that everything's going to be alright, because this world was meant to have him in it, was built to have him in it; so the moment he disappears catches him rather by surprise. I think this may be something we need to be on the watch out for.

Adams is a favourite of ours, and, on one level, this pithy story nicely illustrates the approach of Dicke: be mindful of the process that made you when you try to understand your environment. We are not detached observers of the universe, but are part of it, formed and shaped by its physical laws and our immediate cosmic habitat. *Given that we exist at all*, we should not be surprised that life-sustaining environments exist, even though the majority of the universe is inhospitable to human life.

But some have pushed the accusation of “puddle thinking” too far, supposing that it solves the fine-tuning puzzle.

Consider more closely the puddle's reasoning. Let's name our puddle *Doug*. He has noticed a precise match between two things: 1) his shape and 2) the shape of the hole in which he lives. Doug is amazed! What Doug doesn't know is that, given A) the fluidity of water, B) the solidity of the hole, and C) the constant downward force of gravity, he will *always* take the same shape as his hole. If the hole had been different, his shape would adjust to match it. Any hole will do for a puddle.

This is precisely where the analogy fails: any universe will *not* do for life. Life is not a fluid. It will not adjust to any old universe. There could have been a completely dead universe: perhaps one that lasts for 1 second before recollapsing or is so sparse that no two particles ever interact in the entire history of the universe.

Think about the real explanation to Doug's observation: A (fluid water) + B (solid hole) + C (gravity). If the puddle analogy applies to fine-tuning, what corresponds to A+B+C? What explains the match between what our universe does and what

life requires? The puddle analogy doesn't say. Invoking the puddle against fine-tuning is essentially saying “perhaps a solution exists.” Well, OK, sure, thanks for that, but what could that solution be? Maybe you could go one step further by filling in the blank in the following claim: a universe permits the possible existence of life because _____.

Here's the thing: Doug is *right* to think that the match between his shape and the shape of the hole is worthy of explanation. He is not arrogant to look for an explanation. He would be unwise to dismiss *without good reason* the supposition that he is designed for the hole; after all, if Doug talked to his pals Lock and Key, they too would tell him of their remarkable matching shapes. We understand the puddle; we understand a lock and key; we want to understand fine-tuning for life. But “puddle thinking” is often used as an excuse to dismiss fine-tuning as unworthy of our attention at all. Even Doug knows better than that!

A fine-tuning puzzle

The real conundrum of life in the Universe is not: given that we are here, why do we find ourselves in a universe with the conditions that allow us to be here? The puzzle is: why does a universe with the ability to support life exist at all?

This question is uncomfortable for many because it takes us to the edge of physics. If we ever uncover the ultimate properties of physical reality, we will have reached the end of physical explanations. Either the universe is as it is for no reason, or we must look for a reason beyond physics. The debate is unavoidable but necessarily philosophical. Some invoke a divine mind, a “fine-tuner” who configured the universe to allow us

to be here. Perhaps ours is a synthetic universe, whose conditions were chosen by a programmer who wants to simulate an interesting universe.

Another live option is the multiverse, the notion that our universe is one of many, each with their own physical laws and conditions. In many proposed models of a multiverse, most universes are dead and sterile, but with enough spins of the cosmic roulette wheel, the right conditions for life should show up somewhere. We should not be surprised to find ourselves in one with physical conditions that allow us to be here.

At the moment, the multiverse is a rough sketch of a scientific theory, or more exactly, a collection of sketches. If we had a rigorous multiverse theory, we could predict the variety of generated universes and see whether our universe is rare or common. Just as importantly, we could ask: are life-permitting universe generators as fine-tuned as life-permitting universes?

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The Ellerslie Meteorite: Description and correction to historical find site

William D. Birch

Geosciences, Museums Victoria, Melbourne, Australia

Email: bbirch@museum.vic.gov.au

Abstract

The 10.2 kg Ellerslie meteorite was donated to the National Museum of Victoria in May 1905 by Mr Henry Crawford, who informed the curator at that time that it had been found on the Ellerslie Estate in August 1900. The Ellerslie Estate, which Mr Crawford co-owned, is some 40 km east of Enngonia in northern New South Wales, adjacent to the Queensland border. In an unexplained historical error, the official find site for the Ellerslie meteorite has been recorded as “Tego, Maranoa, Queensland” in the 2000 Catalogue of Meteorites. This paper provides the first formal description of the meteorite, confirming it as an L5 ordinary chondrite showing mild shock features. It also investigates the source of the error in the historical record of the find site.

Keywords: Ellerslie meteorite, find site, historical error, L5 ordinary chondrite, Tego.

Introduction

Historical background

On 27 May 1905, Mr Henry Crawford paid a visit to the National Museum of Victoria (NMV) in Melbourne. He had a gift for the museum, a large and heavy (10.2 kg or 22.5 lb) brown rock that he’d carried all the way from the Ellerslie Estate, which was about 25 miles (40 km) from Enngonia and about 80 miles (130 km) from Bourke, in far-north New South Wales. The Museum’s curator, Richard Walcott, recognised the rock as a meteorite at the time, but it wasn’t registered in the collection until March 1916, when it was given the unofficial name Ellerslie and catalogue number M7336. The date of discovery, August 1900, had been supplied by Mr Crawford after he’d received a note from Walcott on the day after the donation. Locality information was later provided to Thomas Hodge-Smith, Curator at the Australian Museum in Sydney, who was compiling a

list of Australian meteorites. In the resulting paper, published in the Australian Museum Memoirs in 1939, Hodge-Smith stated that the meteorite was “known 1905” from the Ellerslie Estate, “about 80 miles north of Bourke, New South Wales,” which was the locality as entered in the NMV’s register. To this information, and without providing a source, Hodge-Smith added the clarification that “the locality is across the Queensland border.” Ever since, Ellerslie has been listed officially as a Queensland meteorite, but as the original record clearly indicates, it came from New South Wales.

History of investigation

At the time of its registration in the NMV collection, the Ellerslie meteorite was a complete stone measuring approximately $26.7 \times 17.3 \times 12.2$ cm with a mass of 10.2 kg (Figure 1). The meteorite probably remained intact until December 1962, when a 28.7 g piece was sent to Brian Mason at the Ameri-



Figure 1: The Ellerslie meteorite photographed in 1972. Note the prominent regmaglypts and the near complete fusion crust. MV specimen E11444; photographer unknown.

can Museum of Natural History to support his study of olivine compositions in chondritic meteorites. He classified Ellerslie as an olivine-hypersthene chondrite based on its olivine composition falling within the range Fa_{24-25} characteristic of this large group (Mason, 1963). In June 1967, Ray Binns, at the University of New England in New South Wales, was provided with 31.7 g for comparison with other stony meteorites he was studying from the Dirranbandi district in southern Queensland, which is several hundred kilometres to the northeast of Ellerslie. In return, he donated a thin section of the meteorite to the NMV. Later in 1967, Binns submitted reports on two of the so-called “Dirranbandi” meteorites, Wynella (H4) and Hamilton (L6), in the form of letters to the Commission on Meteorites of the International Geological Congress, with preliminary information published in *The Meteoritical Bulletin*, no. 42, in February 1968 (subsequently republished in *Meteoritics*, 1970, volume 5, page 96). However,

until this paper, no formal description of Ellerslie appears to have been prepared and published. Brian Mason was supplied with another 28.2 g in October 1972 to enable him to undertake microprobe analyses as part of a comprehensive study of Australian chondrites, but no results were published.

The meteorite

Description

The remaining mass of the Ellerslie meteorite is now on display in Melbourne Museum (formerly the NMV) (Figure 2). It clearly shows a fusion crust that is largely intact, with some well-developed “thumb prints” (regmaglypts). The thin section of Ellerslie donated to the Museum by Ray Binns in 1968 has a cover slip, thereby preventing a complete description and the gathering of microprobe data on the main minerals, including the metallic phases. However, a small sliver of the meteorite was donated for this study by Rainer Bartoschewitz, who had obtained material by exchange in 1984



Figure 2: The Ellerslie meteorite on display in Melbourne Museum. Note the label repeats the incorrect site details. Photograph from Anthony Abell.

(see later). This enabled a polished section to be prepared for the description and microprobe analysis.

Microscopic examination shows poorly defined chondrules up to 1 mm across, with indistinct edges. Discernible chondrule varieties include radial and porphyritic pyroxene (RP, PP), barred and porphyritic olivine (BO, PO) and porphyritic olivine pyroxene (POP) types (Figures 3, 4). The matrix and the chondrule mesostases are fully recrystallised and plagioclase grains are up to 100 μm across but mostly less than 20 μm . Subhedral grains of chromian ferroan spinel to 0.3 mm also occur, in places in contact with metal phases. These are dominated by taenite, kamacite and troilite, which are commonly in contact and in places show textures with troilite blebs included in the metal and associated with grains of native copper (Figure 5). As discussed by Tomkins (2009), such textures are indicative of low-temperature, post-impact metamorphism in ordinary types 3 to 6 chondrites.

Evidence for moderate shock is also present, in the form of undulose to mosaic-like optical extinction in olivine grains, characteristic of shock classification S₃–S₄ (Stöffler et al., 1991). Shock-melted metal (quenched metal droplets in silicate glass) and sulfide melt veins are also observed. While oxidation crusts occur around some of the metal grains, overall rusting appears to be low, consistent with the preservation of a near-complete fusion crust.

Mineral compositions

Representative mineral analyses were obtained using a JXA-8530 field emission electron microprobe in the School of Earth Sciences, University of Melbourne. Olivine analyses are extremely uniform and give an average composition expressed as $\text{Fo}_{74.7}\text{Fa}_{24.7}\text{Te}_{0.5}$, consistent with Mason's determination (Mason, 1963). Orthopyroxene analyses are also uniform, giving rise to an average composition expressed as $X_{\text{En}}=77.5$, $X_{\text{Fs}}=21.0$, $X_{\text{Wo}}=1.5$. Only one plagioclase analysis, expressed as $\text{Ab}_{64}\text{An}_{28}\text{Or}_9$, was obtained

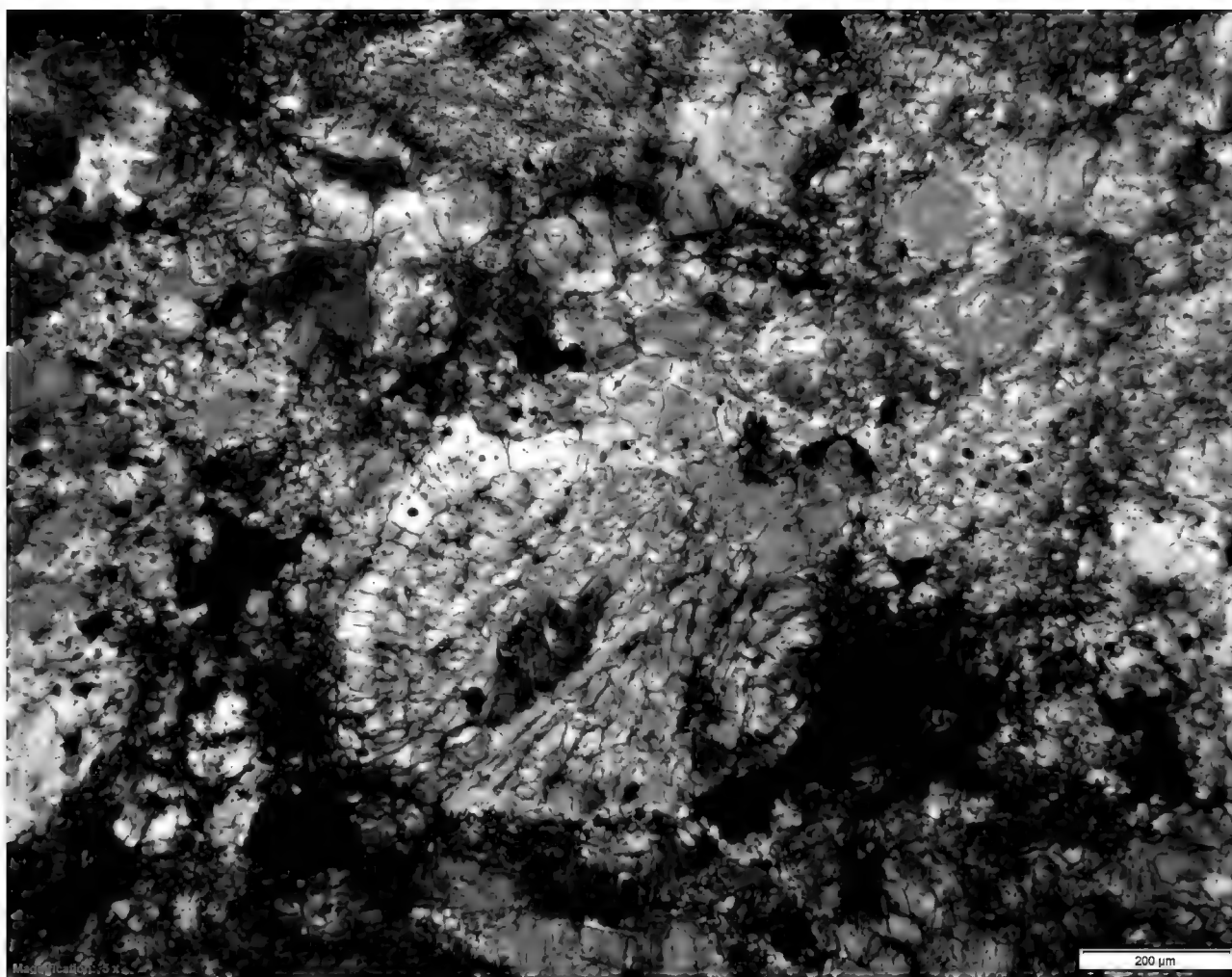


Figure 3: Transmitted light image showing barred olivine chondrule 0.7 mm across.

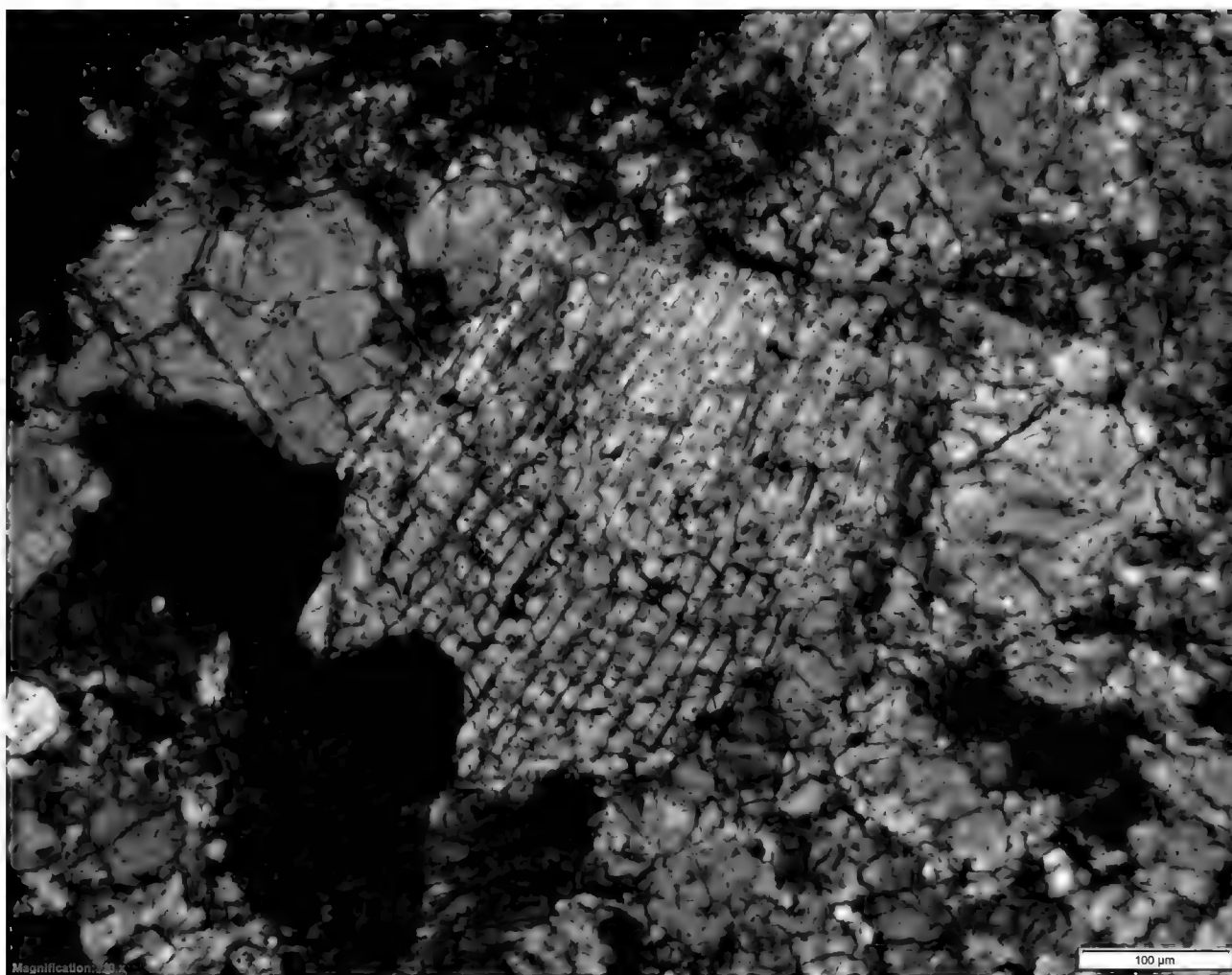


Figure 4: Transmitted light image showing barred olivine chondrule 0.7 mm across.

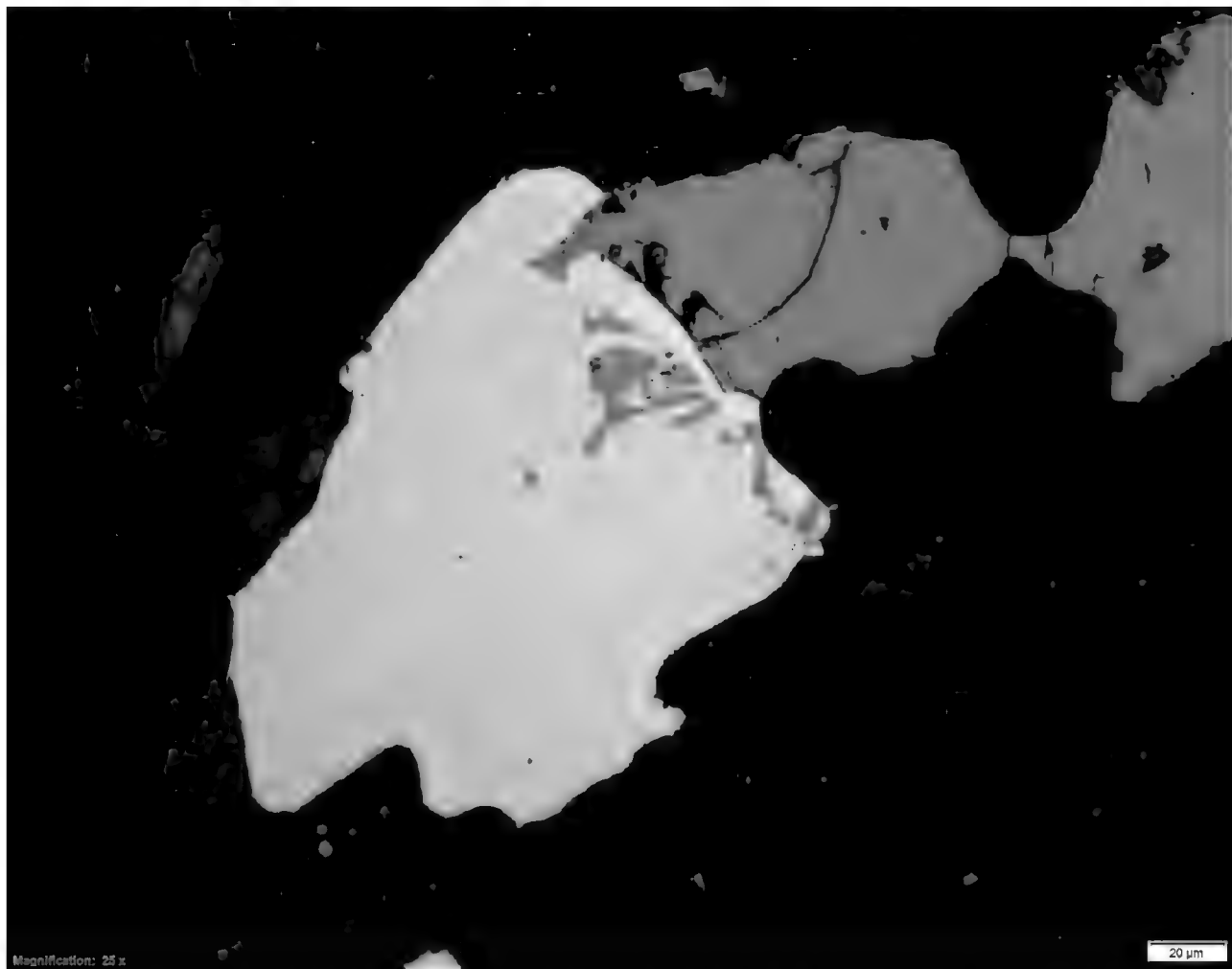


Figure 5: Reflected light image showing taenite grain (white) in contact with troilite (pale brown) and an inclusion of native copper (orange) in the taenite. Note also the troilite inclusions in the taenite. Image is 0.3 mm across.

and no phosphates were detected. The Ni contents of kamacite average 6.4 percent and Co contents average 0.9 percent ($n=22$). The relationship between the Co content of the kamacite and the Fa content in olivine is consistent with values determined for ordinary types 3–6 chondrites (Rubin, 1990). The taenite averages 24.5 percent Ni ($n=14$); no tetrataenite was detected.

Classification

Petrographic features and mineral compositions can be used to distinguish between Types 4, 5 and 6 ordinary chondrites, as the degree of recrystallisation increases with increasing thermal metamorphism (Huss et al., 2006). While the presence of tiny Ca-pyroxene grains in the matrix is diagnostic of Type 5 chondrites, the necessary diligent

search with the microprobe to find these was not possible in this study. Instead, other criteria have been used to classify Ellerslie. Orthopyroxene compositions in Type 4 show considerable variation, whereas those in Ellerslie are invariant, typical of Types 5 and 6. Little significance can be attached to the single plagioclase analysis, given that equilibrated L chondrites may contain a wide range in feldspar compositions and exsolution features (Lewis & Jones, 2016). However, plagioclase grain size is more diagnostic, with distinction between Types 5 and 6 made on the basis of plagioclase grain size in the recrystallised mesostases around chondrules (Huss et al., 2006). In Ellerslie, grains are primarily around 10–50 microns across, characteristic of Type 5, whereas those in Type 6 are more typically 50–>100

microns. These features, together with the olivine composition Fa_{24-25} determined by Mason (1963), support Ellerslie's classification as an L5 ordinary chondrite.

The presence of thin oxide mantles on some of the metal grains is characteristic of grade W1 on the weathering scale of Wlotzka (1993).

Distribution

The mass of the remaining portion of Ellerslie is 9.2 kg (Figure 2), so approximately 1 kg has been removed for distribution to other institutions. Up until 1984, 89 g of that can be accounted for by the pieces sent to Ray Binns and Brian Mason. Since then, some 628 g has been distributed, mainly to meteorite collectors, with all transactions involving exchanges for other meteorites.

This means that Museums Victoria has provided a total of around 717 g for research and exchange purposes. According to the 2000 *Catalogue of Meteorites* (Grady, 2000), some 656.5 g of Ellerslie was held by other institutions around the world at the time of its publication (Grady, 2000, Table 1). This list is incomplete; for example, the Australian Museum in Sydney holds 5.5 g of Ellerslie obtained by exchange in 1973 (Ross Pogson, pers. comm.) and the University of New England holds 24 g remaining from Ray Binn's research (Malcolm Lambert, pers. comm.). There are no records of Museums Victoria exchanging directly with these listed repositories other than the Natural History Museum in Paris, which received 114 g in 1986, and the Rainer Bartoschewitz collection, which received a total of 262 g in

Table 1: Distribution of portions of the Ellerslie meteorite

Location	Weight
US National Museum, Washington, USA	26 g
Natural History Museum, Paris, France	114 g
Max Planck Institute, Mainz, Germany	83 g
Monnig Collection, Texas Christian University, Fort Worth, Texas, USA	35.7 g
Western Australian Museum, Perth, Australia	12.5 g
American Museum of Natural History, New York, USA	0.6 g
Arizona State University, Tempe, Arizona, USA	209 g
Field Museum of Natural History, Chicago, Illinois, USA	9.4 g
Du Pont Collection, Palatine, Illinois, USA	120.7 g
Bartoschewitz Collection, Germany	37.3 g
Institute of Theoretical Physics, Münster, Germany	8.3 g
Total:	656.5 g
<i>Other depositories</i>	
University of New England, Australia (left over from Ray Binn's studies)	24 g
Australian Museum, Sydney, Australia (obtained by exchange in 1973)	5.5 g

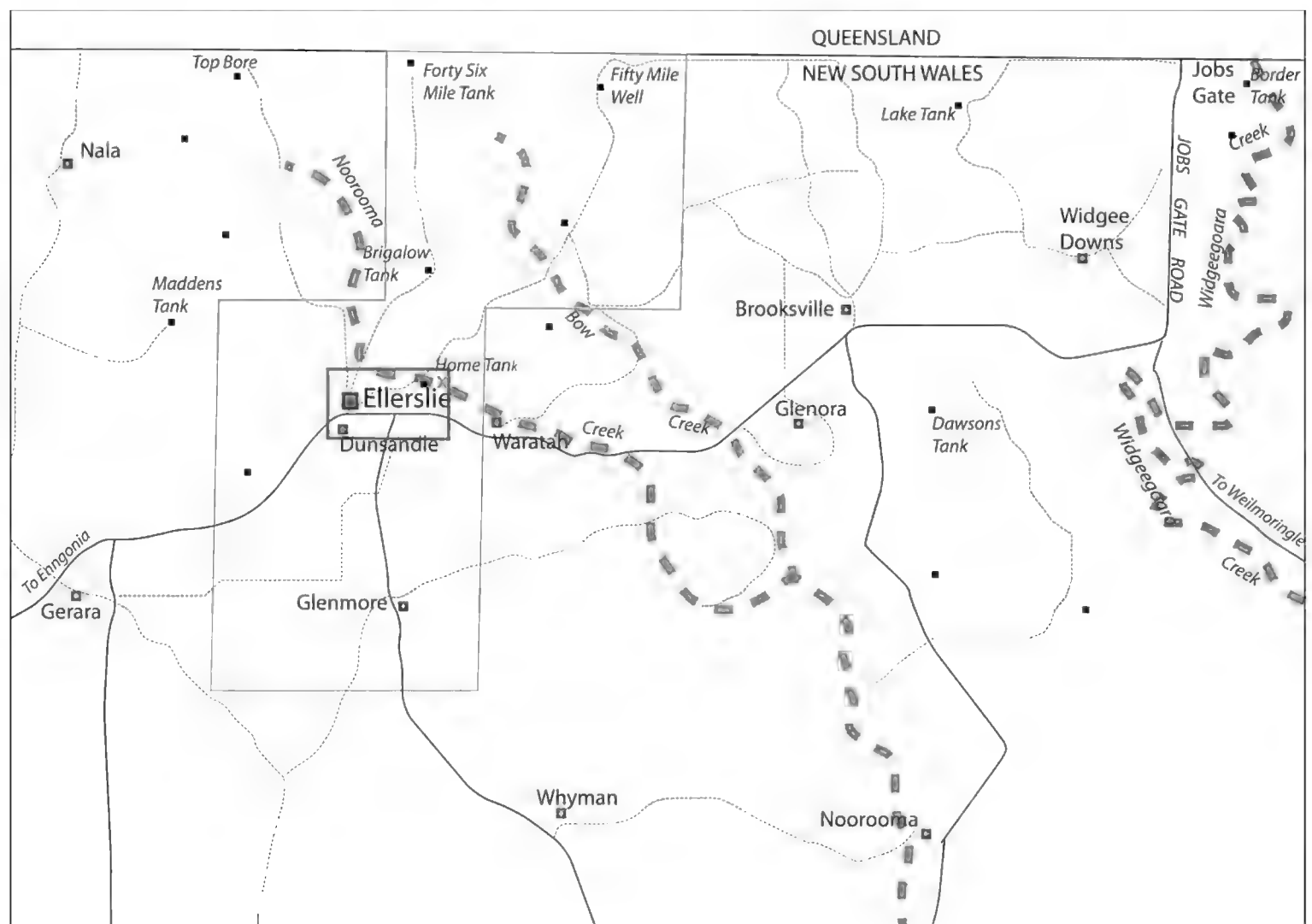


Figure 6: Simplified map of the region around Ellerslie Station, whose present-day boundary is indicated by the red border (as indicated by Mrs Robinson). The inset bordered in green coincides with the Google Earth image shown in Figure 8. The red cross marks the likely find site of the Ellerslie meteorite, on a small claypan within the broad drainage channel of the Noorooma Creek (see Figure 7). The gate (Jobs Gate) through the border into Queensland is near the top right corner of the map.

1984. These figures indicate that most of the latter has been exchanged to organisations on the list in Table 1, and that there are about 280 g unaccounted for, some of which probably arose from loss during slicing.

The find site

Anyone checking the official *Catalogue of Meteorites* (Grady, 2000) would read that Ellerslie was found at “Tego, Maranoa, Queensland,” a puzzling change in the find site. Perhaps this had come about in an attempt to set a more accurate location than just “about 80 miles north of Bourke” and at the same time placing it “across

the Queensland border.” Just to be clear about the location of the Ellerslie Estate, the author approached Mrs Nancy Robinson, who has lived on Ellerslie, now known as Ellerslie Station, for over 50 years. She confirmed that the station is and always has been entirely within New South Wales, with its northern boundary coinciding with the border with Queensland (Figure 6). The property now covers 31,000 acres (12,545 hectares), but it should be noted that its boundaries have changed considerably over time, as various neighbouring “paddocks” were absorbed or lost through purchases and sales.



Figure 7: Claypan typical of those in the area near the find site (photo from Nancy Robinson).

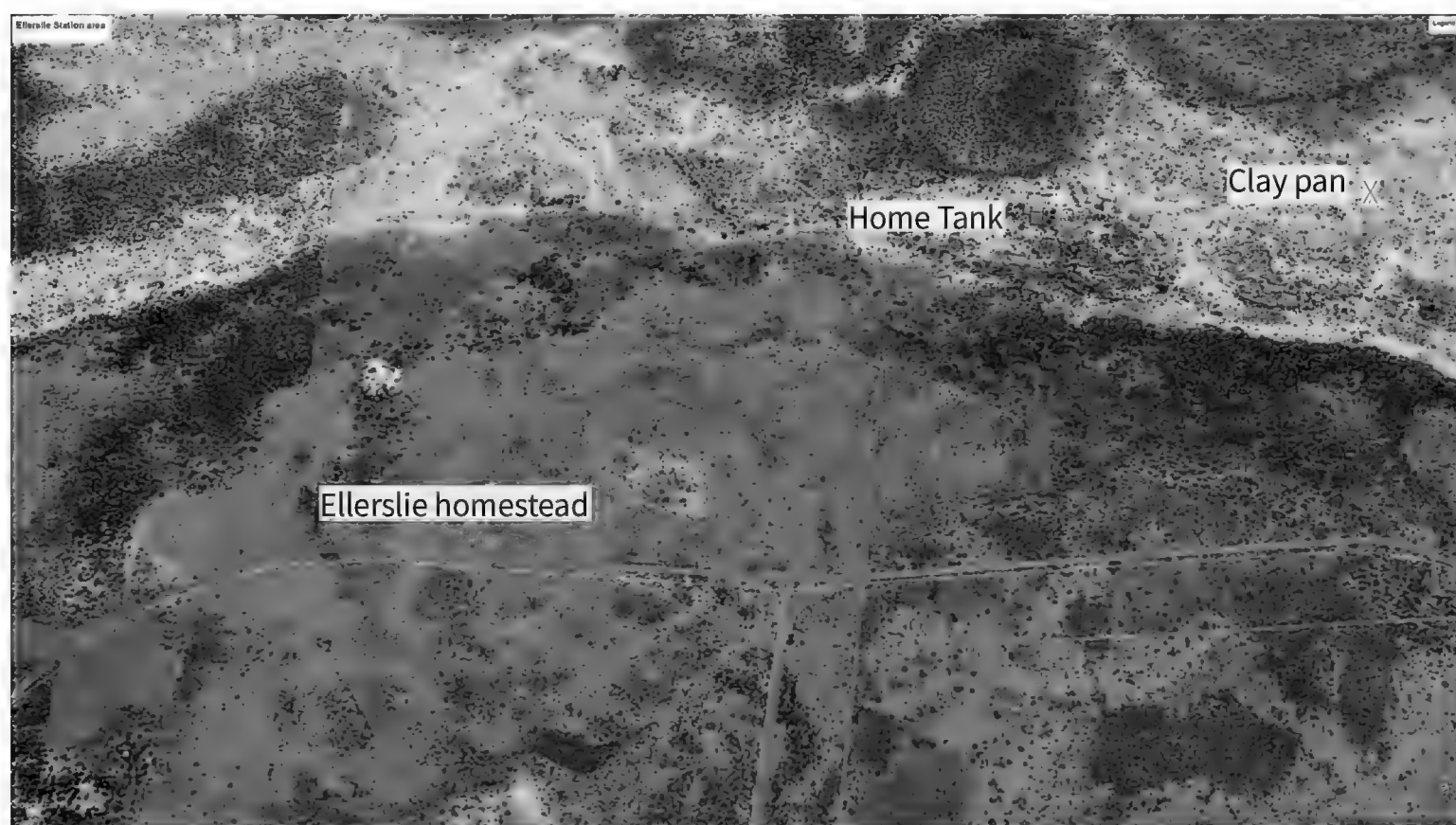


Figure 8: Google Earth image showing the location of Ellerslie homestead, the Home Tank and the find site of the meteorite (refer to Figure 6).

The Ellerslie district is within the Glenmore Land System, which is a region of stony and sandy plains supporting open mulga and areas of woody shrubs, spinifex and grasses (Hunter, 2015). In such a landscape, a large meteorite on the surface might be conspicuous, but Mr Crawford did not provide any specific information about where on the property he found it. However, according to Mrs Robinson, some long-time residents of the district recall that the meteorite was discovered on a clay pan to the east of the Home Tank (Figures 7, 8).

But where or what is Tego? Amongst the earliest appearances of the name is on a plan of runs or blocks shown in the *Atlas of Bundaleer Plains and Tatala*, produced by Frederick Montague Rothery between 1877 and 1878. Tego and Tego North runs are situated to the west of Nebene Creek and north of Widgegoarra Creek in the southernmost portion of the Bundaleer Plains, then a large pastoral property within Queensland's Maranoa district, as it was then constituted (Figure 9). The history of these blocks is complicated, mainly because leaseholders came and went, and names changed frequently (Butlin & Jennings, 1970). On the Maranoa Run Map of 1883, the Tego run is renamed Tego Springs in reference to an intermittent natural spring found within its boundaries. In 1899, a Tego township was gazetted on the site of a former settlement adjacent to the springs but was never built. A parish with that name has existed through the 20th century in the County of Nebine and is now included in the Shire of Paroo. Tego is also the name of the springs, or an artesian bore, in the Culgoa Floodplain National Park

(Figure 10). This region can be reached via Jobs Gate Road, about 20 km north of Job's Gate on the State boundary fence some 60 km northeast from Ellerslie (see Figure 6).

While this history records the name Tego, it doesn't explain how or by whom the name was attached to the meteorite site. The most likely explanation is that it was an attempt to locate it "across the Queensland border" and, for unknown reasons, Tego was chosen as the most appropriate name. Tego was in use, possibly informally, by 1967, when Ray Binns, then at the University of New England, New South Wales, wrote to the NMV requesting a sample for study. By then, the meteorite had been reregistered as E11444 in May 1968.

The finder

The meteorite's finder, Henry Crawford, is a mysterious figure. Research has revealed that he was born in the early 1860s in Castlemaine, in central Victoria, one of nine children born to parents who emigrated from Glasgow in 1857. It appears that Henry moved to New South Wales in his mid-teens, probably on his own, and eventually reached the Bourke district by the 1890s. He married Ann Cowan during a brief visit to Melbourne in 1902–3, and the couple went back to Ellerslie, living there until the property, which they co-owned, was sold in 1914. Henry had returned several more times to Melbourne, delivering the meteorite in May 1905, then to donate more samples of rocks and minerals from Ellerslie to the NMV in December 1906. After Ellerslie's sale, Henry and his wife returned to Melbourne, where they lived in a rented house in Nicholson Street, Carlton, with two of his sisters. After living briefly

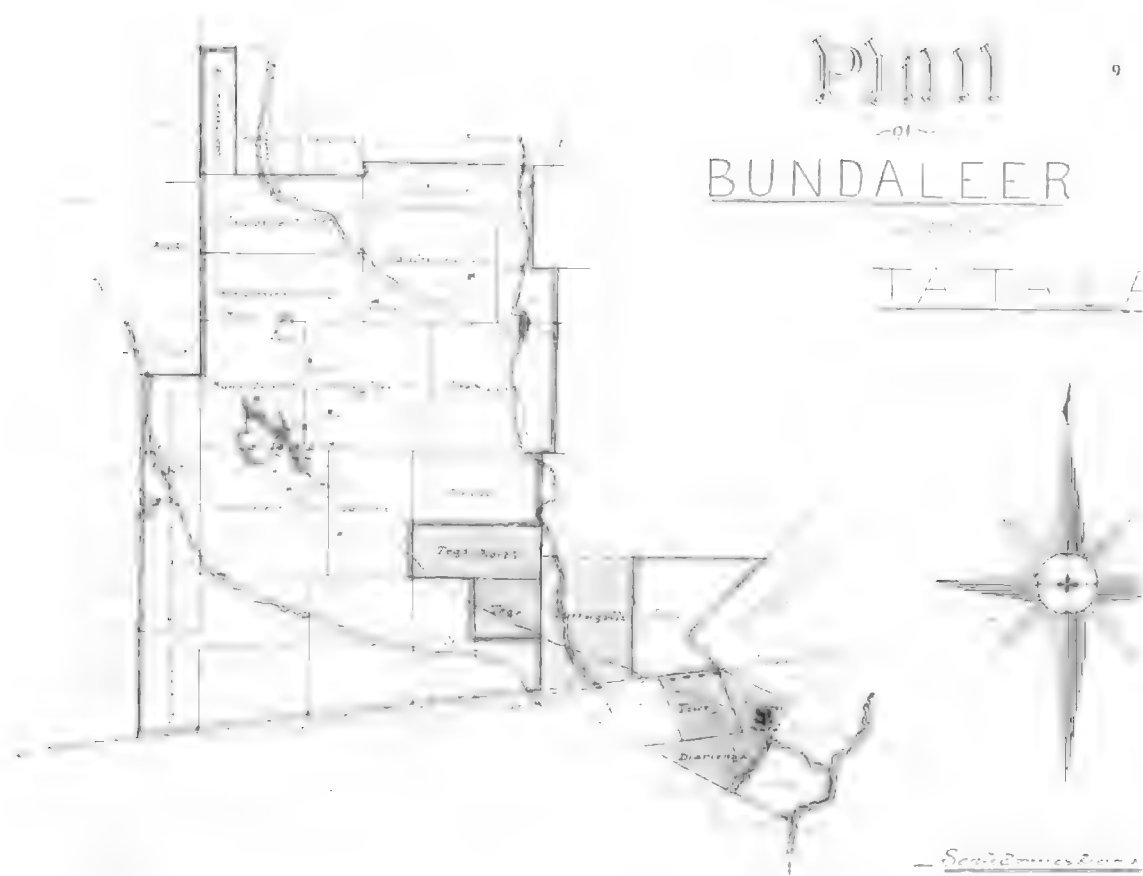


Figure 9: Plan of the Bundaleer Plains and Tatala showing positions of the Tego and Tego North runs in 1878 (see text).

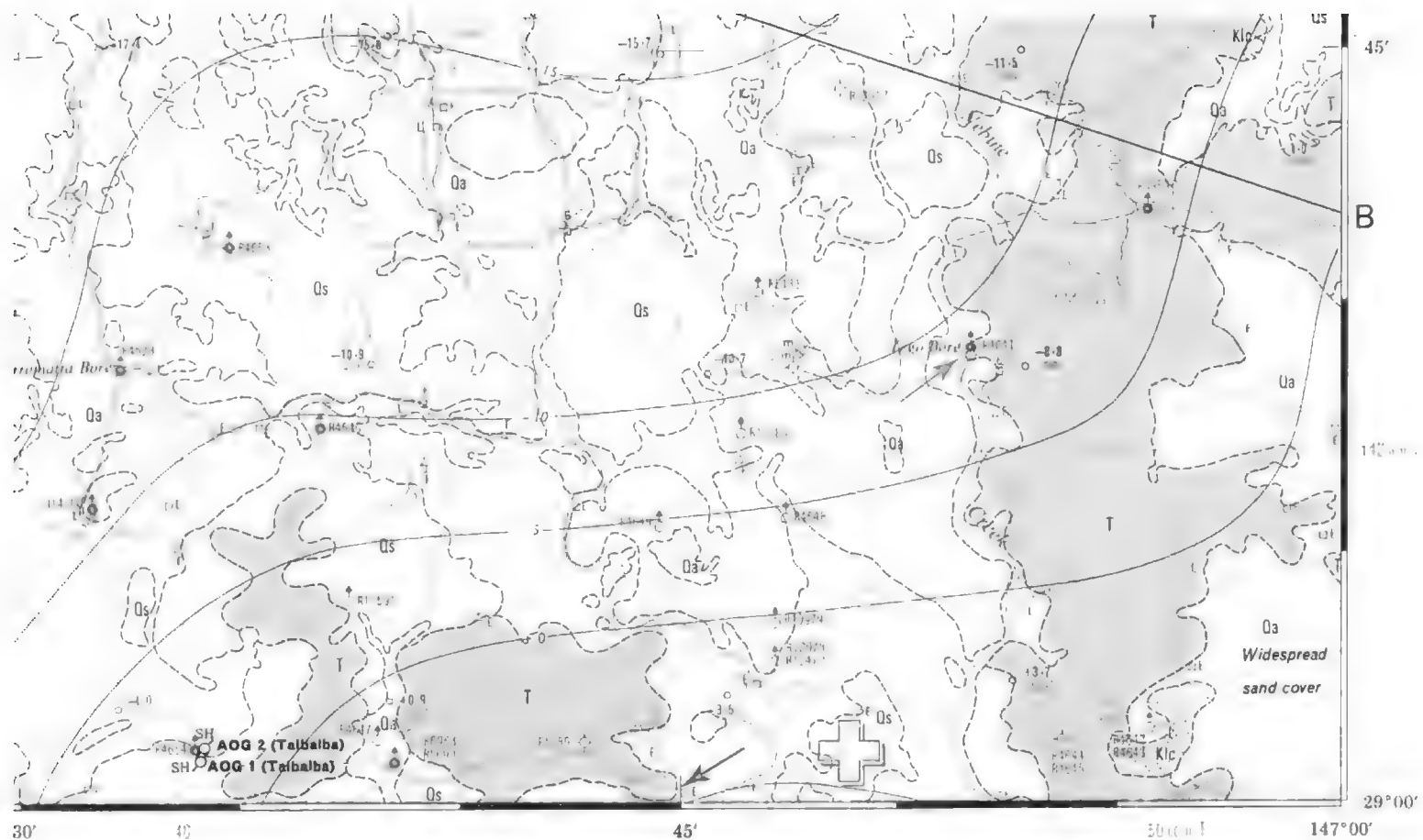


Figure 10: Part of the Cunamulla 1:250,000 geological map (Bureau of Mineral Resources 1968) showing the location of Tego artesian bore (red arrow) and Jobs Gate (green arrow) on the Queensland border (see Figure 6).

in Burke Street in the city, Henry died in Prahran in February 1925 from a form of lymphatic cancer, for which he'd been treated for years. Bearing in mind that the journey from Ellerslie to Melbourne in the early 1900s involved taking a coach from Enngonia to Bourke, then trains through central New South Wales to connect to Albury, then on to Melbourne, it might be expected Henry had good reason to travel so far other than to donate geological specimens, especially when a 10-kg meteorite would have imposed logistical difficulties. There are no records of any business interests he had in the city; instead, it's more likely his visits were for medical treatment. He left his estate, worth £3386, to his widow, who died in 1934; they had no children.

Summary

This investigation of the history of the Ellerslie meteorite has confirmed that it was discovered in August 1900 on the original Ellerslie Estate on the New South Wales side of the border with Queensland. The finder, Henry Crawford, was a co-owner of Ellerslie and made several visits to Melbourne in the early 1900s, during one of which, in May 1905, he donated the meteorite to the National Museum of Victoria. The official record of its find site being "Tego, Maranoa district, Queensland" is based on an historical mistake whose origin this investigation has sought to trace, but ultimately without success. Despite pieces of Ellerslie being widely distributed in international institutions, this paper provides the first known formal description of the meteorite, which is classed as an L5 ordinary chondrite showing mild shock features. A preliminary summary of this information has been added to the *Meteoritical Bulletin's* online database.

Acknowledgements

The author is grateful to Andy Tomkins (Monash University School of Earth, Atmosphere and Environment) for the petrographic description, advice on classification, and photography. Graham Hutchinson (School of Earth Sciences, University of Melbourne) obtained the microprobe analyses during a period when the author was unable to access the equipment due to the COVID-19 lockdown. Rainer Bartoschewitz (Gifhorn, Germany) generously donated a sample of the meteorite for investigation. Without the assistance and enthusiastic support provided by Mrs Nancy Robinson of Ellerslie Station, the historical record could never have been corrected. Nik McGrath and Anthony Abell at Museums Victoria assisted with archival and image resources, and Ross Pogson (Australian Museum) and Malcolm Lambert (University of New England) provided information on their respective institutions' holdings of the meteorite.

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Self-sensing cement-based sensors for structural health monitoring toward smart infrastructure

Wengui Li, Wenkui Dong, Arnaud Castel, Daichao Sheng

School of Civil and Environmental Engineering, University of Technology Sydney, Australia

Email: wengui.li@uts.edu.au

Abstract

Since its first appearance more than 100 years ago, concrete has had a significant impact on urban development — buildings, roads, bridges, ports, tunnels, railways and other structures. While traditional concrete is a structural material without any function, a new branch of concrete technology has produced smart (or intelligent) concrete, with superior self-sensing capabilities that can detect stress, strain, cracks and damage, and monitor temperature and humidity. With the incorporation of functional conductive fillers, traditional concrete can exhibit electrical conductivity with intrinsic piezoresistivity. This piezoresistivity means that the electrical resistivity of concrete is synchronously altered under applied load or environmental factors. The self-sensing electrical resistivity thus obtained can be an index or parameter to detect stress or strain changes in concrete, or cracks and damage to concrete. On the other hand, because of the relationship between electrical resistivity, temperature and humidity, self-sensing concrete can also monitor environmental factors. This smart self-sensing concrete can therefore be a promising alternative to conventional sensors for monitoring structural health and detecting traffic information from concrete roads, all of which are critical to achieving smart automation in concrete infrastructures.

Introduction

In addition to their mechanical strength and durability, the question is asked as to why a concrete structure needs intrinsic functionalities, such as damage and crack sensing capacity as well as temperature and humidity monitoring ability. When we think of the heartbreaking news reports of terrorist attacks, accidental explosions, bushfires and earthquake disasters happening in the world, we remember the images of people injured or killed by the unexpected collapse of the structures around them, because they were not warned in advance to escape from these dangerous buildings (Kaewunruen, 2008; Nurse, 1956). However, in smart self-sensing concrete buildings with damage/crack detection and temperature and

humidity monitoring properties, people inside those structures can be alerted in a timely manner when the structures become unstable and unsafe (Chung, 2012; Dong, 2019a). In addition, and based on the structural health monitoring (SHM) messages given out by self-sensing concrete structures, construction agencies can make their own decisions on whether to demolish or repair the damaged infrastructure.

Traditional concrete contains water, cement, and fine and coarse aggregate. Self-sensing concrete has one addition of functionally conductive filler (Warren, 1901; Ou, 2009). The purpose of functional conductive fillers, bearing in mind that they do not significantly weaken the strength and durability of concrete, is to improve the volumetric conductivity of concrete, which

is normally considered as an electrically isolated material. Basically, some carbon and metal materials as conductive fillers provide concrete not only with enhanced electrical conductivity but also with improved strength and durability. Carbon nanotube (CNT) and nanocarbon black (CB) are two particularly popular conductive fillers for self-sensing abilities to detect damages/cracks and monitor humidity and temperature in concrete (Dong, 2020b). Compared to traditional concretes, the mechanical and durability performance of smart self-sensing concrete is also improved due to the fibrous bridging effect of CNT and CB (Materazzi, 2013; Howser, 2011).

How can an increase in electrical conductivity in concrete introduce the function of detecting and monitoring damage or cracks? In the case of a commercially available foil strain gauge, for example, the deformation of the strain gauge can transfer to the electrical resistivity changes in the sensitive alloys fixed to the plate. Similarly, deformations or strain can be displayed by the electrical resistivity changes of self-sensing concrete, which incorporates conductive fillers. Once the relationship of the electrical resistivity to damage, stress, strain, temperature and humidity is determined in the calibration process, the self-sensing concrete becomes a cement-based sensor that can be embedded in infrastructures for structural health monitoring or traffic flow information detection.

The data acquisition system of self-sensing concrete is similar to that of a conventional strain gauge. To obtain electrical resistivity changes, a multimeter and power supply should be provided. In addition, two or four electrodes are attached to the concrete, based on either the two-point or four-point method. Two alternatives of electrode

configuration, namely either embedded or surface electrodes, can then be selected (Li, 2020). Electrical signals can be collected automatically to analyse their changes and determine the type and magnitude of the forces to which the concrete is under. An amplifier might be used to magnify the electrical resistivity changes. Thus, structural health monitoring using self-sensing concrete with cement-based sensors can detect load capacity and the specific degree and type of external force on a structure.

Production of cement-based sensors

Raw material

For the mix design of self-sensing concrete, carbon or metal materials, such as CNTs or nano CB, are usually used as conductive fillers. In addition, the application of conductive rubber products with cementitious materials shows satisfactory conductivity and piezoresistivity (Dong, 2020). When carbon materials are selected (due to their nanoscale sizes and high surface energy), special treatments should be carried out to ensure good uniform dispersions.

Treatment of conductive filler

Is the manufacture of smart self-sensing concrete as simple as manufacturing traditional concrete? As is well known, after preparing raw materials, traditional concrete production consists of the main procedures of mixing, casting and curing. The manufacture of self-sensing concrete requires only one extra procedure, namely the dispersion of conductive fillers for the mixture. Given the very small size of the conductive fillers used, they may agglomerate and further influence the mechanical property of self-sensing concrete. Conductive fillers are therefore treated before mixing to reduce the number and size

of agglomerations. As a result, the dispersion process is adopted to separate the conductive fillers to ensure they can connect to each other and form conductive networks in the cement matrix (Konsta-Gdoutos, 2010; Ma, 2010).

Ultrasonic treatment of solutions with conductive fillers is critical to separate agglomerated carbon nanomaterial. However, it should be noted that both sonication time and intensity also affect the dispersion efficiency of carbon nanomaterials. Prolonged sonication may increase the temperature of the solution which then causes the re-agglomeration of carbon nanomaterials. Moreover, especially for fibrous carbon materials such as CNTs and carbon nanofibers, long-term sonication at high intensity might damage the fibrous structures of conductive fillers. Another treatment to disperse carbon nanomaterials is chemical dispersant and surfactant. This method coats the surface of carbon materials to reduce the mutual attraction among nanoparticles.

Manufacturing procedure

Once a uniformly dispersed solution with conductive fillers had been prepared, the mixing procedures and specimen casting of self-sensing concrete were similar to those of traditional concrete (Milner, 1964), following standard of ASTM C305-14 (Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency). Specifically, the self-sensing concrete was compacted using a vibration table. Copper meshes were inserted into the fresh specimen materials during this vibration process to enhance the cohesion among electrodes and concrete in order to reduce the interferences from contact resistivity. Finally, the self-sensing concrete with embedded electrodes was cured in a standard chamber in a temperature of 23 ± 2 °C and relative humidity of 90%. The basic manufacturing process of self-sensing concrete as cement-based sensors with CNTs is shown in Figure 1.

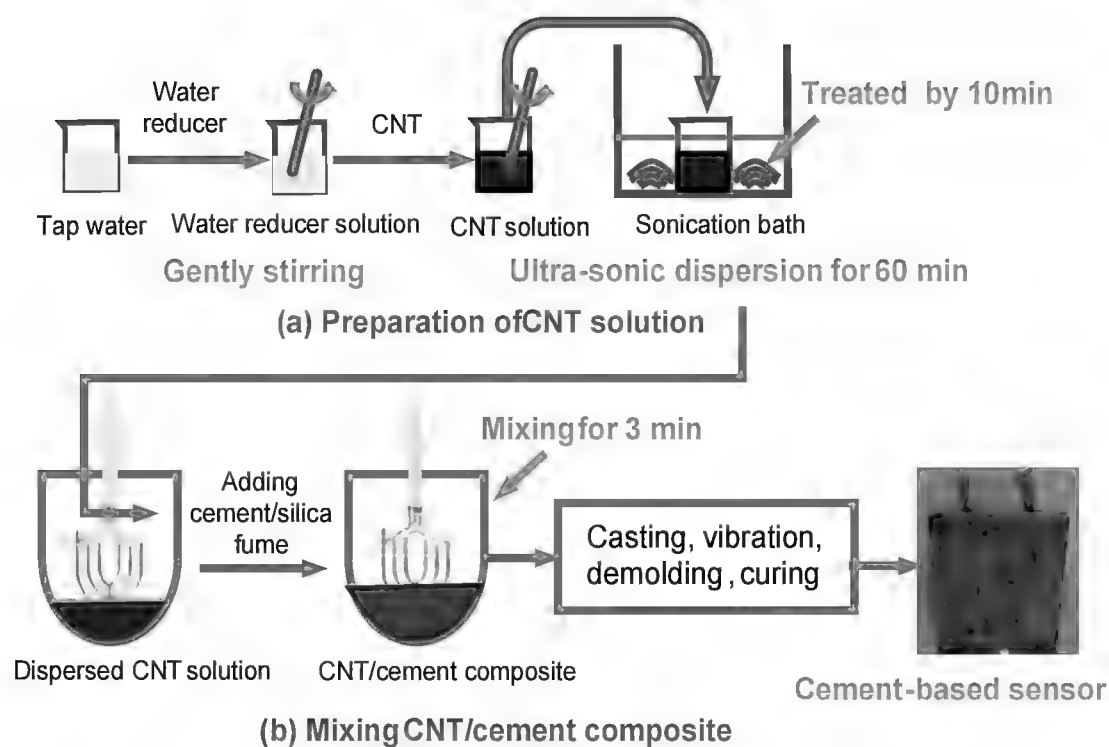


Figure 1: Manufacturing process of self-sensing concrete as cement-based sensors

Activation and calibration

The activation of self-sensing concrete as a cement-based sensor includes calibration, preservation, and electrical current design. The calibration was the initial electrical resistivity of cement-based sensors preset as the initial state, so that altered resistivity could be related to applied external forces or deformations. The reliability and repeatability of self-sensing concrete as a cement-based sensor means that the initial electrical resistivity should remain constant during its service life. For example, electrical resistivity changes in self-sensing concrete should be due only to the forces applied to the structures; other environmental factors such as temperature and humidity should be eliminated. A temperature compensation circuit or specific hydrophobic coating can be used to eliminate the effect of temperature and humidity. Similarly, for cement-based temperature sensors, the influences of external forces or humidity should in a practical application be eliminated. The current design of self-sensing concrete as a cement-based sensor is critical to obtaining reliable piezoresistivity signals. The variables consist of direct (DC) or alternate (AC) current, the intensity of electrical current supply and its frequency

(for DC), and whether a two-point method or four-point method is used. These factors affect the measured electrical resistivity and directly influence the accuracy and reliability of cement-based sensors.

Self-sensing performance

Piezoresistivity is a physical property of self-sensing concrete defined as the change of the electrical resistivity when subjected to mechanical loadings (Rovnaník, 2019). For self-sensing concrete as a cement-based sensor used in SHM, when a uniaxial compression is applied, the inter-particle distance of the conductive fillers changes and new conduction paths are created. Hence, the closer the conductive particles are, the more easily an electrical current can flow, decreasing the electrical resistivity. During unloading, the concrete material returns to its relaxed state and the initial resistivity is recovered, provided there is no plastic deformation. Overall, this phenomenon may be seen as piezoresistivity. Based on the above concepts, piezoresistive cement-based strain sensors were established. The piezoresistivity performance of smart self-sensing concrete was then tested, including the compressive machine, digital multimeter, control panel and data collection system, as shown in Figure 2.



Figure 2: Piezoresistive performance of self-sensing concrete under compression

Stress and strain self-sensing

The electrical resistivity of self-sensing concrete as a cement-based sensor with damage and crack sensing capacity altered when it was subjected to external loadings. For instance, the sensing performance of self-sensing concrete with conductive CNTs can be seen in Figure 3. The applied compressive stress was arranged in three cycles of cyclic loading with an increasing stress magnitude of 4 MPa, 6 MPa, 8 MPa and 10 MPa. The compressive strain was obtained by the foil strain gauge attached to the surface of the specimens, and their electrical resistivity

changes were collected by the digital multimeter. It can be seen that the fractional changes in the resistivity of self-sensing concrete with CNTs were highly consistent with the compressive stress/strain. Generally, the ratio of strain to electrical resistivity was named the gauge factor, which is proposed for the sensing efficiency evaluation. For commercially available foil strain gauges, the value of the gauge factor is normally 2. However, the gauge factor of self-sensing concrete with conductive functional fillers can reach several hundred, which means great potential to assess the stress/strain and damage/crack conditions of concrete infrastructure.

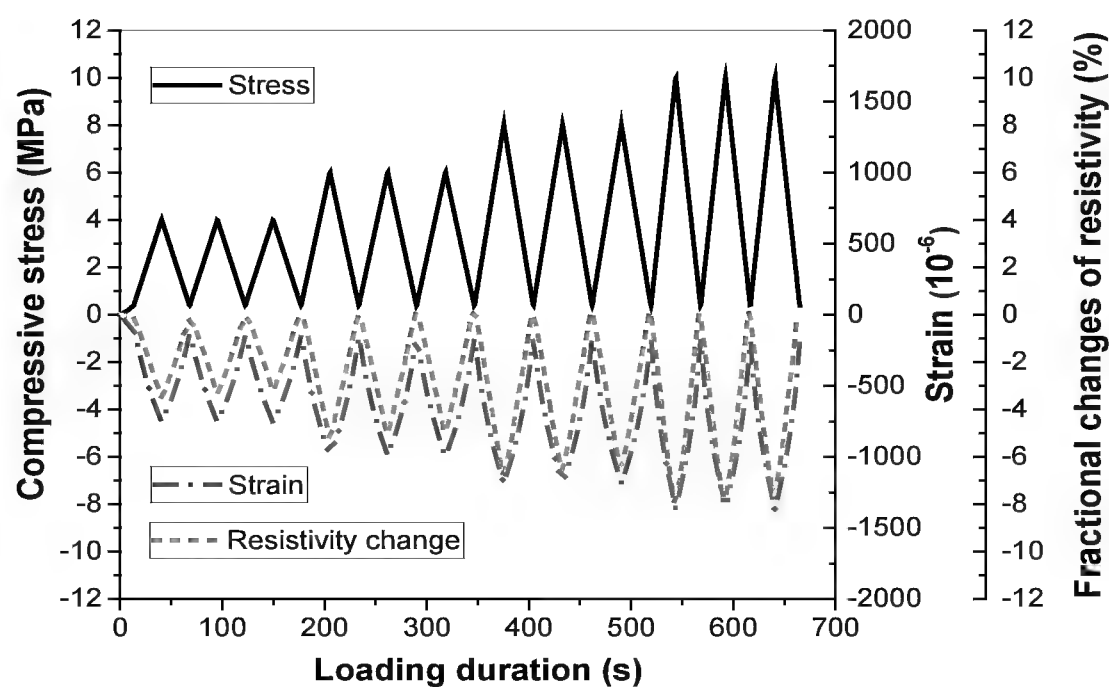


Figure 3: Stress/strain performance of self-sensing concrete with CNTs

Damage and crack detection

The above results were based on stress applied directly onto the self-sensing concrete. The next test was the performance of self-sensing concrete for SHM, such as embedded cement-based sensors in a concrete beam. In the case of beam failure detection, it was

found that the electrical resistivity of embedded self-sensing concrete gradually increased with the increase in bending stress, as shown in Figure 4. Because the cement-based sensors were embedded in the compression zone of concrete beams, the cement-based sensors were subjected to compressive load,

which was why the electrical resistivity decreased. The fractional changes in resistivity achieved the highest value when the concrete beam reached the ultimate state of flexural strength. Afterwards, once the concrete beam was damaged, the loading stress

suddenly decreased and the electrical resistivity simultaneously changed. Consequently, sudden changes in the electrical resistivity of self-sensing concrete can be used as a cement-based sensor to detect whether or not the state of full destruction is reached.

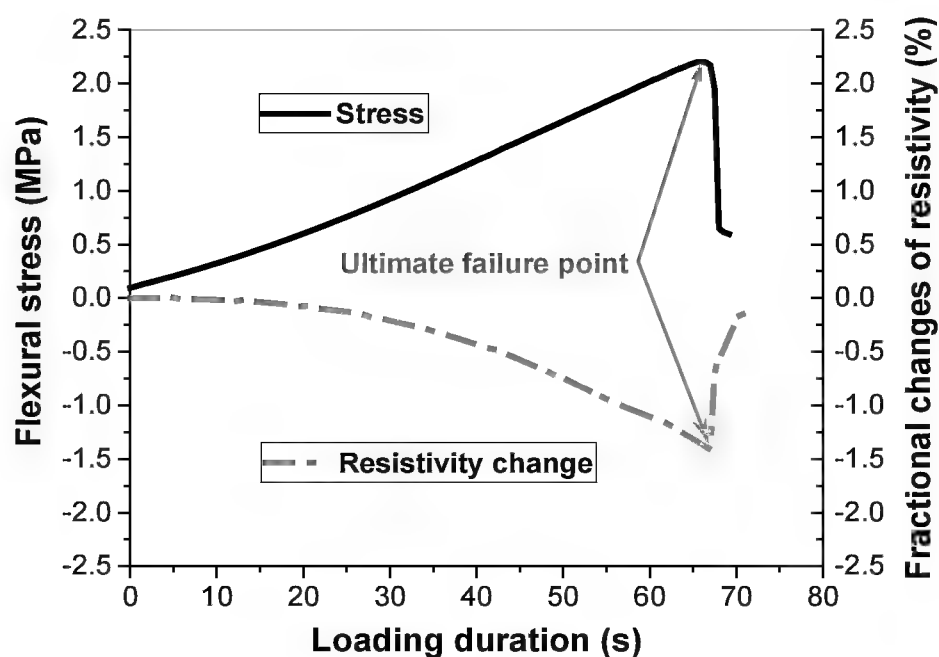


Figure 4: Piezoresistive behaviours of cement-based sensor embedded in concrete beam

Temperature monitoring

Self-sensing concrete can monitor temperature variation based on changes in electrical resistivity. However, given that it takes time to reach the equilibrium between the ambient temperature and the internal temperature of the concrete, there might be continual changes in the electrical resistivity of smart concrete at the beginning when the external temperature changes. An increase in temperature lowers the electrical resistivity of self-sensing concrete, and this altered electrical resistivity is possibly due to the changed viscosity and ionic activity of pore solutions (Dong, 2019b; Dong, 2020b). When the temperature falls from 100 °C to -20 °C, the electrical resistivity gradually increases and returns almost to its initial values. The slightly altered electrical resistivity of

self-sensing concrete subjected to subzero temperature is mainly due to the freezing of pore solutions which themselves cause minor damage in the concrete. For temperature cycles above 0 °C, the electrical resistivity exhibits excellent consistency with the temperature. Hence, the electrical resistivity can be a perfect index to monitor the temperature of both concrete and the ambient environment. However, as mentioned previously, the freezing of pore solutions and damage to the microstructures of smart concrete might lead to an extra increase in the electrical resistivity, which can disturb the repeatability of electrical resistivity during temperature detection. Therefore, a self-sensing cement-based sensor is recommended for monitoring temperature of pore solutions only above freezing point.

Humidity monitoring

The water content of self-sensing concrete relates closely to the electrical and piezoresistive properties, due to the moveable ions inside pore solutions. Normally, with any decrease in water content, the electrical resistivity increases and vice versa. Based on the investigation on the self-sensing concrete with a high dosage of nanocarbon black (CB) (Dong, 2019a). The low electrical resistivity of self-sensing concrete with 3% CB indicates conductive passages inside of composite are effectively established. Previous studies have shown that with the increase of water content from dry state to saturation state there is a gradual increase in electrical resistivity. Therefore, higher water content induces more moveable ions and decreases electrical resistivity, while an increase in resistivity is mainly due to strengthened ionic conduction and weakened electric conduction. Given a high concentration of CB, the direct contact between CB nanoparticles leads to strong electric conduction and significantly improves the electrical conductivity of cementitious composites. In addition, the efficiency of electric conduction in reducing electrical resistivity is better than that of ionic conduction. With an increase of water content, some nano CB particles are enclosed by a water film, which

results in a strengthened ionic conduction and an increase in contact resistivity among conductive fillers. These two factors are responsible for the increase in the electrical resistivity of concrete with 3% CB. This implies the correlation between electrical resistivity and water content inside self-sensing concrete as cement-based sensor and their great potential for monitoring the humidity or water content of concrete infrastructures.

Future application

Figure 5 schematically demonstrates the application of self-sensing concrete as cement-based sensors to achieve smart/intelligent concrete infrastructures. For instance, concrete building integrated with cement-based sensors can automatically detect damage and cracks and monitor temperature and humidity to provide structural health condition information and alert people to escape from structures that have become dangerous. Cement-based sensors can also be used in bridges and tunnels to identify deformations, monitor cracks and provide alarms for differential settlement and leakage. In particular, intelligent motorways with self-sensing cement-based sensors could detect traffic volume, vehicle speed and even vehicle weight very accurately.

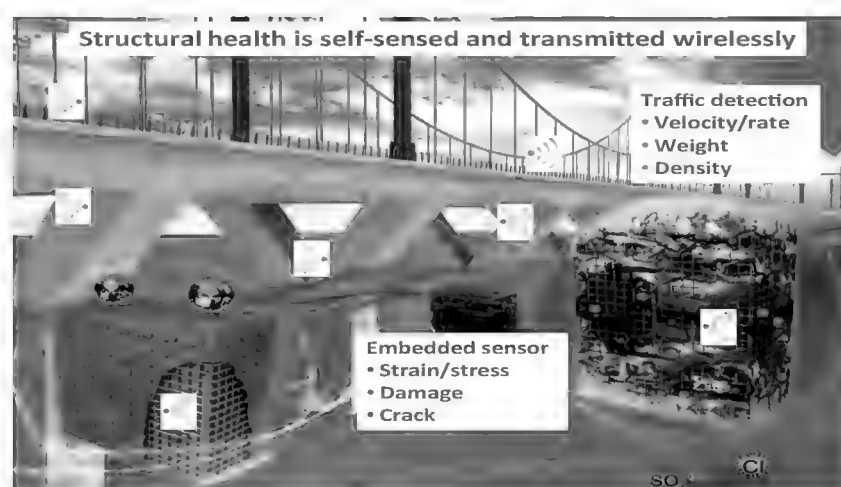


Figure 5: Potential application of self-sensing cement-based sensor for structural health monitoring and traffic detection

Advantages

In view of the many other structural damage detection techniques available, such as piezo ceramic, optical fibres and strain gauge, there is the question why the application of self-sensing concrete as a cement-based sensor to self-monitor damage, stress or strain conditions is promising. First, the cost of self-sensing concrete is much lower than that of other sensor systems. Second, the sensitivity of self-sensing concrete is much higher than that of conventional sensors. For instance, the gauge factor (a coefficient for sensitivity evaluation) for a foil strain gauge is usually 2, while the value of intelligent concrete can reach several hundred and show much higher sensing efficiency. Third, the durability of self-sensing concrete is many times greater than that of conventional sensors. Conventional sensors might have a service life of several month or years, but the durability of self-sensing concrete is as high as traditional concrete, which can be used for decades. Last but not least, the cohesion of self-sensing concrete to concrete structures is much stronger than that of non-intrinsic sensors. Typically, the mechanical properties and durability of concrete structure are not significantly affected by cement-based sensors as an introduction of foreign material, rather than the piezo ceramic and optical fibres.

Challenges

Self-sensing concrete is influenced by factors such as temperature and humidity variations, which hinder its practical application for SHM and traffic detection. Cement-based sensors with conductive fillers are similar to semiconductors, whose electrical resistivity can be greatly affected by ambient temperature, because of the altered movements of

ions, electrons and pores. This means that, except for the specific loadings applied, the fractional changes in the resistivity of self-sensing concrete might be induced from temperature and humidity variations which affect its stress/strain and temperature/humidity sensing accuracy and reliability. To solve these problems, this study has proposed the application of a supplementary temperature circuit to completely eliminate the effect of temperature on the electrical resistivity. Moreover, ambient humidity affects the water content of self-sensing concrete in that it directly alters its electrical resistivity, because several types of ions such as Ca^{2+} , OH^- , and Al^{3+} are movable in solutions. Actually, in addition to the conductive fillers, these ions in the pore solutions of self-sensing concrete might make a considerable contribution to its self-sensing capacity. It might improve the stress/strain and temperature/humidity sensing efficiency when the self-sensing concrete has appropriate water content. To reduce the impact of external humidity, self-sensing concrete shows excellent water impermeability, which means it can be used in various working conditions, such as harsh and coastal environments. In addition, the layout of cement-based sensors inside of concrete structures and data collection system should be investigated.

Conclusion

Self-sensing concrete in the form of cement-based sensors can be applied in multiple concrete structures for structural health monitoring and traffic detection, for the detection of stress/strain and cracks or other damage, and to monitor temperature and humidity. It possesses the advantages of lower cost, higher sensing efficiency, better durability and serviceability than that of

conventional sensors. Most importantly, it provides the conventional concrete structures with a multifunctionality that can automatically monitor their structural health status.

Acknowledgements

The authors appreciate the support of the Australian Research Council (ARC) (DE150101751; IH150100006; IH200100010) and University of Technology Sydney Research Academic Program at Tech Lab (UTS RAPT).

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The *Helicobacter* story

Robert Clancy AM FRSN

University of Newcastle, NSW, Australia

Email: robert.clancy181@gmail.com

Abstract

These presentations occurred at the Ordinary General Meeting of the Royal Society of New South Wales, at the State Library, Sydney, on 11 November 2020, with the title, “Where have all the ulcers gone, long time passing?” as the first of several proposed talks on Great NSW Discoveries.

The life of a medical resident 50 years ago was dominated by peptic ulcers — 10% of men would get a duodenal ulcer, which caused pain and distress often occasioning admission to hospital for a milk drip, or worse if surgery had been “earnt,” resulting often in some form of deforming surgery that usually swapped one set of symptoms for another. Each year 2 to 3% would have a life-threatening complication — usually a bleeding or perforated ulcer.

The world changed in a dramatic fashion in 1981 when Robin Warren and Barry Marshall described an association of ulcers with spiral bacteria, now able to be seen due to the recent introduction of direct vision gastroscopy and biopsy. By swallowing the bacteria, Marshall showed that they caused gastritis, but not ulcers.

To prove that the bacteria caused ulcers required treatment that could eradicate the infection.¹ The Perth doctors were unable to develop such treatment, with others also failing around the world. This is the story of two NSW individuals (both Fellows of the Royal Society of NSW), whose critical contributions enabled a good idea to be translated into a dramatic health change, proving the link between *Helicobacter pylori* bacteria (as the spiral organisms came to be known) and ulcers to be causative, and facilitating a range of important discoveries.

¹ From the Koch postulates. As originally stated, the four criteria are: (1) The microorganism must be found in diseased but not healthy individuals; (2) The microorganism must be cultured from the diseased individual; (3) Inoculation of a healthy individual with the cultured microorganism must recapitulate the disease; and finally (4) The microorganism must be re-isolated from the inoculated, diseased individual and matched to the original microorganism. — Segre, J. A. (2013). What does it take to satisfy Koch’s postulates two centuries later? Microbial genomics and *Propionibacteria acnes*. *J Invest Dermatol*, 133(9), 2141–2142. [Ed.]



Adventures with spiral bugs and *Helicobacter*

Adrian Lee FRSN

University of New South Wales, Sydney, Australia

Email: adrianlee2@mac.com

These adventures began in 1967 when I was lucky enough to get a post-doctoral fellowship at the Rockefeller University in New York. This was in the laboratory of René Dubos, a distinguished microbiologist who was the first to systematically find an antibiotic, to pioneer the investigation of *Mycobacterium tuberculosis*, but who recently had become interested in the microbial flora of the intestinal tract (Moberg, 2005). Indeed, Dubos really can be considered to be the Father of the gut microbiome, which is currently all the rage, sixty years later (Prescott, 2017). His group worked with germ-free (GF) and specific-pathogen-free (SPF) mice, studying the bacteria in their intestinal tracts and the impact of factors such as nutrition, stress, maternal care, housing conditions, social interactions and sanitation on immune functions and health over the lifespan of the mice.

With colleague Russell Schaedler, Dubos was the first to consider the digestive tract as an ecosystem. In their words: “Recent studies have revealed that there exists in normal animals an abundant and characteristic microflora, not only in the large intestine but also in all the other parts of the digestive tract ... they become so intimately associated with the various digestive organs that they form with them a well-defined

ecosystem in which each component is influenced by the others and by the environmental conditions.” (Dubos & Schaedler, 1964).

So there I was, poised to work with Schaedler and Dubos on their SPF mice convinced that “the indigenous flora is responsible in some part at least for a number of physiological and immunological traits both favorable and unfavorable which are commonly assumed to have a genetic basis.” By chance, I was there at the beginning of the gut microbiome. How right their hypothesis turned out to be.

What was I to do? It was clear that many of the bacteria in the mouse intestinal tract had never been grown. Under the microscope, the dominant microorganisms were pointed or fusiform-shaped bacteria, which had certainly never been cultured.

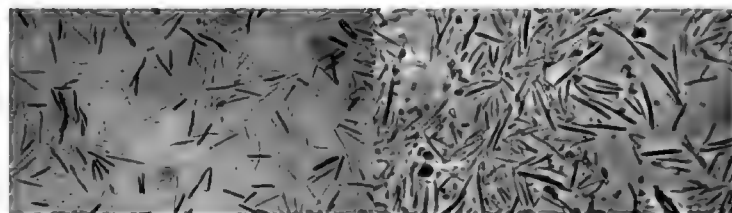


Figure 1: Mouse faeces with fusiforms

That was my task, to grow these fusiforms. Using one of the first ever anaerobic chambers, we succeeded, and to my delight my first publication was in the journal *Nature* (Lee et al., 1968).

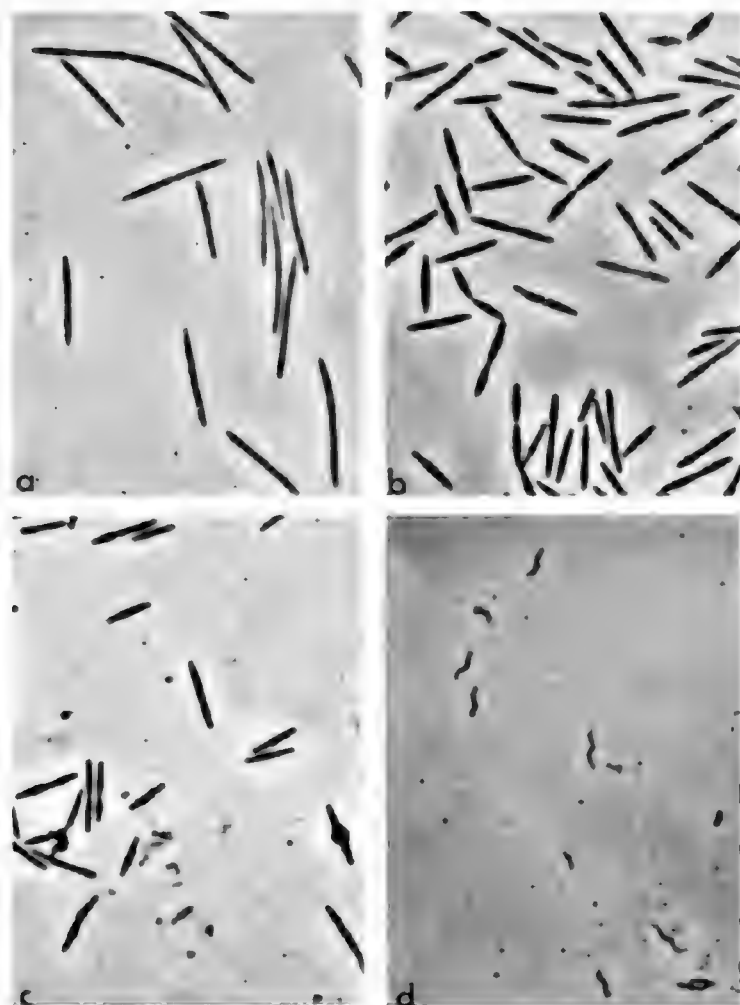


Figure 2: The culture published in *Nature*

Growing gut bugs became my passion for the next forty years. Arriving at UNSW in 1968, a special focus became the bacteria that lived in intestinal mucus, particularly those with a spiral morphology. They packed the intestinal crypts of most animals. One fascination was: why were they spiral? We grew them early on, our favourite being a beautiful organism we called “Stubby,” and tried to convince the NHMRC that these bacteria were worth studying (Leach et al., 1973; Lee & Phillips, 1978; Phillips & Lee 1983). This was made much easier by the discovery of a major diarrheal pathogen, also a spiral organism, *Campylobacter jejuni*. In mouse experiments, we showed that this organism also colonized intestinal mucus (Lee et al., 1986).

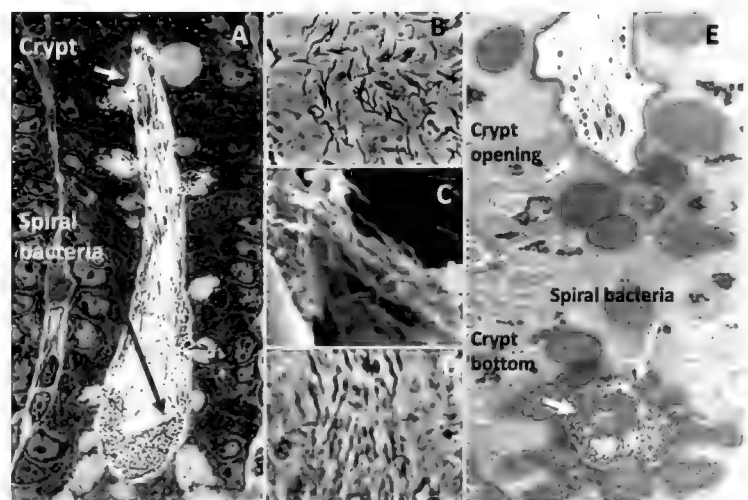


Figure 3a: Spiral bacteria in mouse

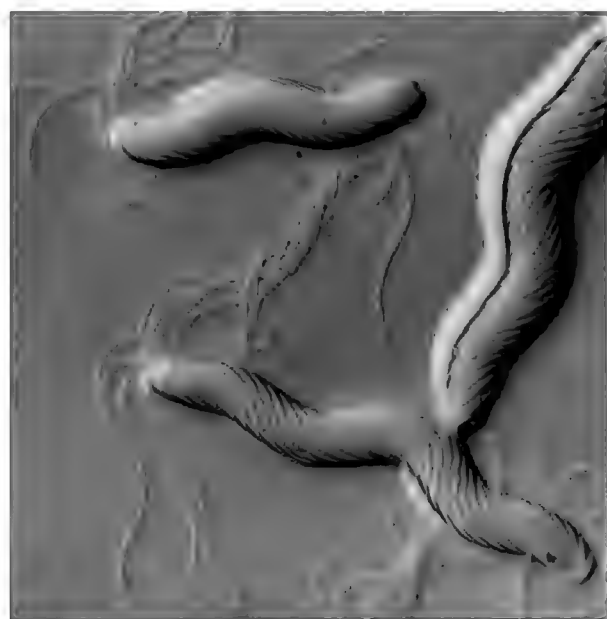


Figure 3b: Stubby: an early cultured bacterium

This work took us to Brussels in 1983 to the Second International Workshop on *Campylobacter* Infections, where we attended a presentation by another Australian that was to change my life. A Barry Marshall was presenting a paper on a bug he had grown from the human stomach and he was suggesting it could play a role in gastritis and duodenal ulceration. I had not met Barry then but had had contact with him. He had written what turns out to be an historic letter from Port Headland to one of my PhD students, Michael Phillips. He wanted to know what we thought about his stomach organism. He had used the conditions we had used to grow Stubby to grow it.

PORT HEDLAND REGIONAL HOSPITAL

P.O. BOX 63,
PORT HEDLAND, W.A. 6721
Telephone: (091) 73 1244
Extension:
Telex: 99133
Our ref:
Your ref:

Michael Phillips School of
Microbiology
University of NSW
PO BOX 1
KENSINGTON NSW 2033

Dear Michael

We have been finding spiral bacteria in the gastric antrum of man since 1979 and believe it is associated with gastritis. The bacteria can be seen on on gram stains, silver stains of biopsies, and has been cultured regularly at Royal Perth Hospital. Dr Doug Annear has viable freeze dried specimens for further study.

While I was in Perth in October Dr Annear suggested I contact Prof. Adrian Lee to ask his advice on the Taxonomy of the bacteria. I have read Bergy's Manual 8th Ed and of course all the references to yours and the Prof's papers and I believe it is yet another species or genus of spirilla.

The organism is unlike the rat bacteria which has axial fibrils and is also unlike spirochaetes seen in the mucosa of the colon in man.



Metabolic studies are under way, results as of October 1982 shown attached sheet.

Please ask Professor Lee for his opinion and perhaps guide me on the path to a few more appropriate references.

Yours sincerely

A handwritten signature in cursive script that reads 'Barry Marshall'.

Barry Marshall MBBS

Figure 4: The Port Hedland letter

By this time, he was trying to get the world to take Robin Warren's and his discovery seriously. He submitted the work to the Gastroenterological Society of Australia for their February 1983 meeting. It was rejected!! "I regret that your research paper was not accepted for presentation — the number of abstracts we received continues to increase for this meeting. Sixty-seven were submitted and we were able to accept fifty-six."

Fortunately for Barry, he had submitted the same work to the *Campylobacter* Meeting. Bacteriologists had not grown up with the gastroenterological dogma of the stomach being sterile and we're always fascinated by the growth of a new organism. In particular Martin Skirrow, who was the leading *Campylobacter* researcher, was intrigued. It was due to him that the work did indeed

get international exposure by a paper in *The Lancet* following their two initial letters (Warren & Marshall, 1983; Marshall & Warren, 1984).

The medical world now became divided into two camps, the Believers and the Non-Believers. The work was eventually presented to the Gastroenterological Society of Australia in 1984 where one delegate reflected "Too Gung Ho. No controls had not even thought of them." Barry did not endear himself to his critics by being convinced he was right and amazed that "they had missed it all these years." Now in 1984, NSW enters the fray. There had been one believer at Barry's talk in Hobart: a Bill Hennessey, Chairman of the Department of Gastroenterology at St Vincent's Hospital, Sydney. He felt it was the "best lecture he had ever heard." He forgave Barry his brashness and felt "he was on to something." Two days after returning to Sydney, he said to microbiologist Jock Harkness "we must do something about this." Jock introduced Bill to me and it all snowballed from there.

At that time a student, Stuart Hazell, was deciding what topic to select for his PhD with me. Given our focus on spiral bacteria, we wanted to examine why they preferentially inhabited intestinal mucus. We decided to compare three spiral organisms *Campylobacter jejuni*, Stubby, and this new bug. Marshall was now calling the *Campylobacter*-Like-Organism (CLO). Stuart started to learn how to grow a culture of CLO that Barry Marshall had sent him. Initially, he had some trouble, but one anaerobic jar with a crack in it seemed to work well. This got us thinking about gas mixtures and so we removed the catalyst from the anaerobic jars we were using and lo and behold Stuart could grow the bug

well. This was good timing, as this was when he went to Bill Hennessey for clinical specimens. They took 10 gastric biopsies and grew the organism from all 10! This got Bill very excited and Stuart started regularly working at St Vincent's. The other two spirals were discarded and studying the CLO became his sole PhD topic. He was remarkably productive, making major discoveries¹ on what was now *Campylobacter pyloridis*. This included the first studies explaining the mechanism of colonization, and he devised one of the first urease tests for diagnosis. Stuart was probably the first person world-wide to get his PhD studying this gastric pathogen.

Also, around this time another PhD student, Hazel Mitchell, was working with material from St Vincent's, looking at the epidemiology of *Campylobacter pylori*. (Another name change!) She devised one of the first serology tests for the organism.² One has to realise that at that time I was young and inexperienced in the commercial world of microbial diagnosis. I refused to let Stuart and Hazel publish on the urease or serology tests until they had many cases, and the idea of patenting anything did not enter my head. Thus, future friend Cliona McNulty published on the urease test on 112 biopsy specimens and beat us to it. Barry patented his CLO test. Likewise, Hazel was pipped to the post. They do still talk to me!

This is where Tom Borody enters the story. He will tell his part in an accompanying article, but it is important to acknowledge the serendipity of the pathway that led Tom

into *Helicobacter* and his major role in world-wide acceptance of *Helicobacter pylori*, as it was finally called, as the cause of peptic ulcer disease. The interest in the organism became so great that a dedicated journal "*Helicobacter*" was born a few years later. Tom's role in the story is summed up by the following comment from David Graham, the editor, in his introduction to the journal (Graham, 1996): "The triple therapy introduced by Tom Borody (Borody et al., 1989) provided a therapy that for the first time could cure the infection reliably." Barry had used bismuth and metronidazole with some success but had not achieved adequate cure rates.

Stuart was in the St Vincent's tea room one day when he walked young gastroenterologist, Tom Borody, fresh from the Mayo Clinic in the USA, to work in the Department. Bill Hennessey had encouraged them to meet and discuss the new research that was going on with the CLO. Tom was intrigued and never looked back. In his enthusiastic, entrepreneurial way he started working with ulcer patients, trying to work out a cure. He even offered to fund the development of Stuart's urease test, which was now being routinely used, and suggested he patent it. Unfortunately, we did not take him up on that!

For the next twenty years, Tom and I researched *H. pylori*, mainly independently, and travelled the world trying to convince the non-believers.

My first big symposium presentation was at the World Congress of Gastroenterology in 1990 (Tytgat et al., 1990) — me talking on the microbiology, David Graham on the epidemiology, Barry on the pathogenesis, friends Mike Dixon on the pathology, and Tony Axon on treatment. An audience of thousands. Head days for a humble microbiologist. I was flown

1 Hazell et al., 1986; Hazell & Lee, 1986; Hazell Borody et al., 1987; Hazell Hennessey et al., 1987; Lee & Hazell, 1988.

2 Mitchell et al., 1988; Mitchell et al., 1989; Mitchell et al., 1992.

all over the world to talk. My rationalization was that my job was to convince clinicians to take this organism seriously. It was remarkable how certain companies worked against accepting antimicrobial therapy for ulcers and how long before this became accepted practice. Now most ulcers have disappeared in the developed world except those caused by NSAID-induced lesions. But that is another story. What I would like to do now is describe the research we carried out over those years and what a fun and rewarding journey it was.

I loved trying to grow spiral bacteria. Having noted that nearly all animals were heavily colonized in their stomachs with spiral bacteria, we used the helicobacter growth conditions and successfully grew these beautiful organisms from cats. Identification techniques revealed, not surprisingly, that they were helicobacters and we named this organism *Helicobacter felis* (Lee et al., 1988; Paster et al., 1991).

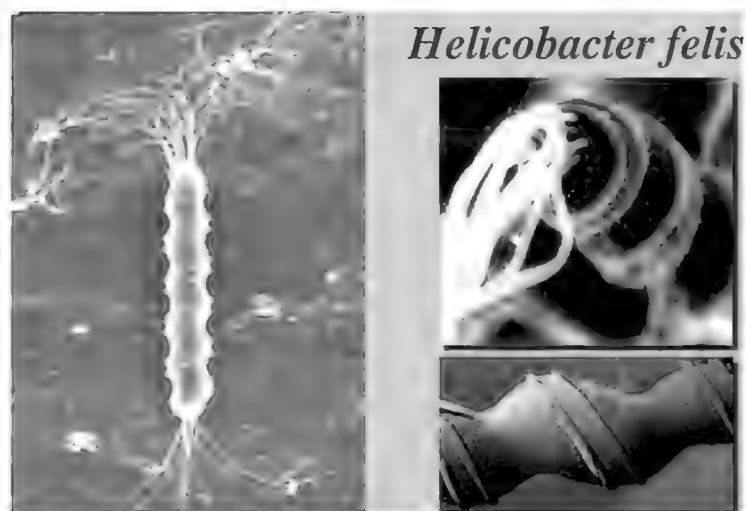


Figure 5: *Helicobacter felis*

There was no convenient animal model of helicobacter infection. It colonized pigs, but this is not very practical. We wondered whether it was worth using *H. felis*. A happy meeting of Jim Fox at MIT provided the opportunity to test this hypothesis. Jim was Head of the Department of Comparative Medicine at MIT and an expert on animal

models, with brilliant facilities in his lab. So it was off to Boston for a sabbatical with a culture of *H. felis* in my shirt pocket to keep it warm. Proper documentation, of course! We put the culture into GF mice, together with another animal helicobacter we had cultured from an infected human.

We hit the jackpot! I vividly remember the first time I looked at sections of the stomach of infected mice. The gastric crypts were packed with the helicobacters and there was clear evidence of inflammation. We had our animal model, which was subsequently used around the world (Lee et al., 1990; Dick-Hegedus & Lee, 1991).



Figure 6: *H. felis* gastritis in GF mice

This allowed us to visualize the answer to that question “Why are they spiral?”

Examination of scrapings of *Helicobacter*-infected mice under phase contrast microscopy revealed spiral-laden crypts full of mucus. The bacteria could be seen boring through the mucus, confirming what culture results in viscous methyl cellulose had showed us. The spiral morphology gives the

bacteria torque in the viscous environment and allows them to move more easily than rod-shaped organisms (Lee et al., 1993).

While the *H. felis* mouse model was successful it was not *H. pylori*. Thus another step forward was when Jani O'Rourke isolated a culture of *H. pylori* from a gastric biopsy that would colonise mice. Patriotically we called it the Sydney strain and so another mouse model was found, again used by many around the world (Lee et al., 1997). One of our most exciting uses of these models was when we proved we could successfully immunize mice against helicobacter infection and even demonstrated a therapeutic effect (Chen et al., 1992; Doidge et al., 1994; Lee & Chen 1994). Our letters to *The Lancet* were noted by CSL, and so began a major seven-year collaborative project seeking a vaccine against *H. pylori*.³ We even got the US patent for therapeutic immunization (Doidge et al., 1995).⁴ Up to fifty million dollars was spent on this project until it was dropped, as there was not considered to be likely profit in immunisation in the developing world. Of all the diseases I could have tried to produce a vaccine on, I would choose a disease that was disappearing from the developed world! The other vaccine project CSL was working on at the same time was Ian Frazer's Human Papilloma Virus vaccine, which was a lot more successful.

Barry Marshall and Robin Warren had proposed that *H. pylori* infection could cause cancer. With our mouse model we showed that long-term *H. felis* infection caused gastric lymphoma, indistinguishable to the disease found in some *H. pylori*-

infected humans (Enno et al., 1995). Others later showed that gastric adenocarcinoma also occurred in long-term infection in our mouse models (Rogers & Houghton, 2009). This work resulted in me being one of the six helicobacter researchers on the panel of eighteen of the International Agency for Research on Cancer (IARC) Working Group on the Evaluation of carcinogenic risks to humans: Shistosomes, liver flukes and *Helicobacter pylori* (IARC, 1994). During this week-long meeting we rigorously reviewed the published literature on each agent and voted on our conclusions. Having only a third of the panel with expertise on each agent reduced the chance of bias in the voting. It was a vigorous and exciting process with the final evaluation concluding that "There is sufficient evidence in humans for the carcinogenicity of infection with *Helicobacter pylori*." A very far-reaching conclusion world-wide.

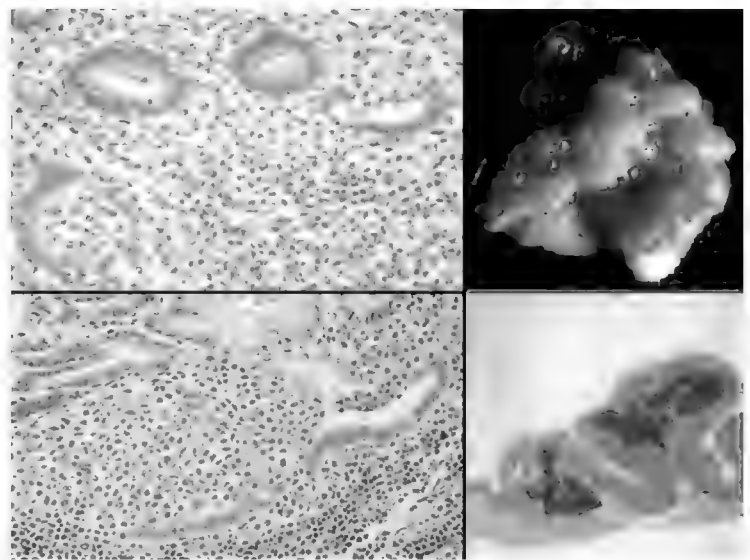


Figure 7: MALT lymphoma lesions

There are many other results of our endeavours over the years, but there is not time to describe them here. But it worth describing the tongue-in-cheek hard-luck story of my research career we described in a book Barry Marshall edited called *Helicobacter Pioneers* (2002). Barry gathered together chapters

³ Vaccine project goes commercial, *Uniken*, 25 October 1996, p.3.

⁴ US Patent WO 95/03824 CSL/UNSW Licensee AstraZeneca.

from all those who had a claim to being the first discoverers of *H. pylori*. This book should be compulsory reading for all those interested in the serendipity of science. Our chapter was called “We grew the first *helicobacter* and did not even know it.”

Strike 1: When Barry sent us that letter from Port Hedland in 1983 asking if we thought his new bug was the same as Stubby, we said: “It is possible that your isolate may belong to a new genus ... I am sorry we cannot be of more help, however the taxonomy of the spiral organisms associated with the gastrointestinal mucosa is, as you will be aware, very poorly understood.” What we should have said was, “We are fascinated by this very interesting and important bacterium. Please send us one of Dr Annear’s cultures to us so we can use our considerable experience with this type of bacterium to help you identify it quickly”!

Strike 2: We were convinced Stubby was a new Genus and submitted a paper proposing the name *Mucospirillum ileocryptum* General nov., sp. Nov. The name was rejected, as we only sent in two cultures to the journal. It turned out later that Stubby is in fact a *Helicobacter*, *Helicobacter muridarum*. Due to the taxonomic rule of precedent, if they had accepted our name, we would now all be talking about *Mucospirillum pylori*! (36).

Strike 3: Remember that very first *Nature* paper in 1968 where we were all excited we had grown the fusiform bacteria? Inspection of the reprints thirty years later revealed an image I had taken no interest in at the time. The fourth panel of images of our cultures clearly showed a pure culture of spiral bacteria. We now know, based on all our work on these organisms since, that they

were almost certainly a *Helicobacter* species. We really had grown the first one and had not known it!

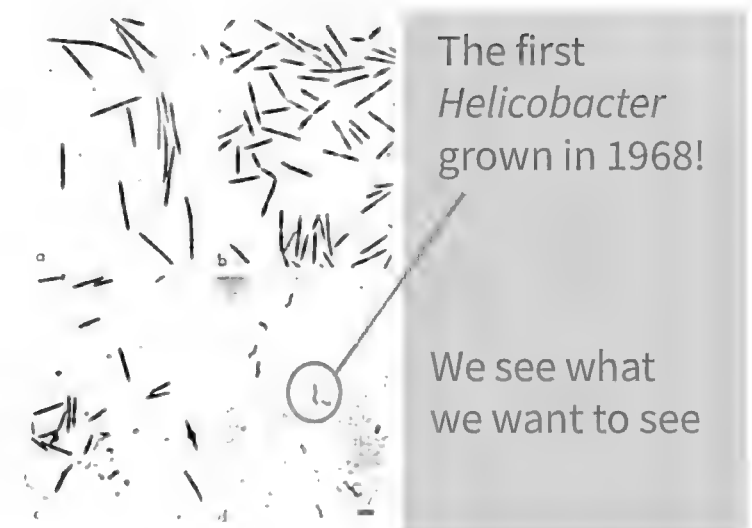


Figure 8: The first *Helicobacter* in 1968

But all was not bad. There were many rewards over the years. We did in fact grow a new spiral genus which we got to name and could honour my Rockefeller mentor Russell Schaedler. We named it *Mucispirillum schaedleri* (Robertson et al., 2005). Recently this organism was shown to have a role in protection against salmonella infection in mice, which is exciting (Herps et al., 2019).

We travelled to some wonderful places, including Rome in 2000 where we were presented to the Pope in front of half a million in St Peter’s Square. Barry and Robin both invited my wife and me to the Nobel Ceremony in Stockholm on 10 December 2005, which turned out to be a pretty special way to close down my research career, as I had moved to the dark side: university administration.

The *Helicobacter* story is a wonderful example of the need to keep an open mind in science. Indeed, for a number of years I told the story to medical students in their first lecture, telling them, “During your

medical course and beyond you will be exposed to, and will discover, the current medical dogmas in many facets of your work. Wonder at how far we have come but be prepared to challenge, disprove, and even discover the next paradigm shift.”

Thank you. It is now time to hear Tom Borody’s story of the NSW *helicobacter* days.

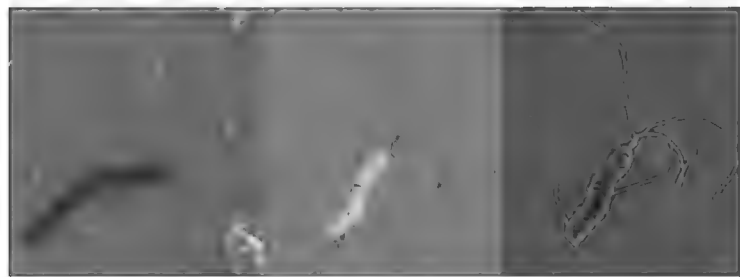


Figure 9: *H. pylori* coloured

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Helicobacter pylori causes peptic ulcers

Thomas Borody

The Centre for Digestive Diseases, Sydney

Email: thomas.borody@cdd.com.au

Abstract

Thomas Borody describes how he and his colleagues developed the Triple Therapy to eliminate the bacteria from the human body, hence confirming their role in ulcer formation.

Introduction

I graduated from the University of New South Wales, and trained in gastroenterology at St Vincent's Hospital in Sydney, followed by a short tropical medicine course at Sydney University, leading to a year of extraordinary life and medicine in the Solomon Islands. This was followed by a period in North America for further training in gastroenterology at the Mayo Clinic.

Returning to Sydney in the early 1980s, I established the Centre for Digestive Diseases, where we were seeing through the gastroscope 2 to 3 new peptic ulcers a day. Acute and chronic peptic ulcers with the complications of the disease and its medical and surgical management was the major part of gastroenterological practise.

A first breakthrough

A breakthrough had occurred with discovery of H₂ Blockers, such as Tagamet, which inhibited acid secretion and healed ulcers. This was seen as proof for the prevailing mantra that hypersecretion of acid was the cause of duodenal ulcers, confirming, as though it was needed, that the research focus on acid secretion was the way to go. When ulcers returned within a year of stopping the H₂ Blocker, the basic tenet simply

became a little more sophisticated, adopting the ulcer equation of Wilfred Card: “acid + pepsin vs. mucosal resistance.” British research even determined a threshold for acid secretion rate, below which you could not develop a duodenal ulcer.

The history of peptic ulcers

The question which no one had an answer for was “what damaged the stomach mucosa to facilitate digestion by acid and pepsin.” The history of peptic ulcers had been forgotten.

In 1889, the Polish physician Walery Jaworski swept up in the “germ theory” wave where there was a new bacterium for every disease, described spiral organisms in the stomach wall, which he called *Vibrio rugula*, and he considered these caused gastric ulcers and cancers. It was not till Warren and Marshall associated spiral organisms with peptic ulcers in 1981 that infection challenged one of the most established “cause and effect” relationships in medicine, as the cause of impaired mucosal resistance.

The problem was that, while Marshall's heroic self-experiment — swallowing the bacteria — showed that they could damage the mucosa, ulcers were not induced. The only way to prove that *Helicobacter pylori*

bacteria (as they came to be called) caused ulcers was to develop treatment that eradicated the bacteria, and show that ulcers not only healed, but stayed healed (unlike the situation with H₂ Blockers, where ulcers would recur). Many attempts using one or two antibiotic combinations were tried, but, at best, were capable of eradicating the bacteria only in a minority of patients.

The Triple Therapy

Helped by the high number of patients with peptic ulcers in the clinic, we explored 36 different combinations of antibiotics, before finding a combination, dose, and duration for therapy that eradicated *Helicobacter pylori* in most patients: Bismuth, Metronidazole, and Tetracycline. Later, we showed that acid suppression further facilitated eradication, and added a Proton Pump Inhibitor to the original “Triple Therapy.”

Three key papers published in the *Medical Journal of Australia* documented the success of Triple Therapy. Two were included in the “ten most quoted papers in the MJA,” published to celebrate 90 years of publication. Two other papers in the “top ten” were those by Warren and Marshall, illustrating the extraordinary contribution made by Australian scientists in Peptic Ulcer disease. The first of our papers was published in 1989, describing the quantitative eradication of *H. pylori* with Triple Therapy, and the healing of ulcers (Borody et al., 1989). The second, in 1990, gave proof that eradication led to cure of duodenal ulcers (George et al., 1990). In 1994, we published a 4–6 year post-eradication report, confirming ulcers remained healed, and that the re-infection rate was of the order of 0.1% per annum (Borody et al., 1994).

Triple therapy, and commercial variants of this therapy, were quickly adopted in all countries. Most popular was a dual antibiotic with a proton pump inhibitor (Nexium Hp-7), which was less effective, leading to the problem of antibiotic resistance. Cure rates fell, while an increasing pool of resistant bacteria and persistent ulcers became a major clinical problem. By then, the link with gastric cancer (involving Adrian Lee¹) was established, and eradication of resistant *H. pylori* took on added importance (Enno et al., 1995).

Quad Therapy and beyond

We developed the next therapeutic milestone of “escape” therapy (or Quad Therapy) based on Rifabutin, which successfully eradicated *H. pylori* in 90% of those with resistant bacteria (Borody et al., 2006). Recently, this number has been increased to 97% by our group, using a potassium channel blocker (Vonoprazan) (Borody et al., 2019).

A recent study examined the impact of *H. pylori* eradication in Australia over a 16-year period, and concluded that Triple Therapy has prevented 18,665 deaths, and saved 258,887 “life years.” Direct and indirect cost savings were estimated, over this period, at in excess of ten billion dollars (Eslick et al., 2020).

Gut biome diseases

Our studies on *Helicobacter pylori* began a long-term research programme in identifying and treating gut disease caused by a disturbed gut microbiome. We developed the idea and then the practical value, of “bulk microbiome replacement” (obtained from normal faeces) for Irritable Bowel

¹ Enno et al. (1995).

Syndrome, *Clostridium difficile* infection, and most recently, chronic ulcerative colitis. Although these Faecal Microbiome Transplant therapies are crude, better definition of specific bacteria using new technologies, and improved replacement bacteria methodology, will transform our understanding and management of a range of gut — and systemic — diseases. We have noted significant improvement in a number of systemic diseases including Parkinson's disease and autism. These exciting observations not only give hope for new therapies for many diseases not previously linked to an abnormal microbiome, but focus attention on the role played by the microbiome in both normal and abnormal body function.

Most recently, we initiated the first effective randomised controlled trial of a combination antibiotic triple therapy for Crohn's disease, often resulting in years of remission (Agrawal et al., 2020).

The future

The focus on managing host-parasite relationships at mucosal surfaces has been extended to the airways, with current studies focussed on triple therapies for late-onset asthma, and COVID-19 infection (based on Ivermectin). Thus, research to improve management of cryptic intracellular infections at mucosal sites has a continuous history at the Centre for Digestive Diseases, for over 40 years.

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An appreciation

Peter Baume AC DistFRSN

Medical Education Student Office, University of New South Wales, Sydney, Australia

Email: p.baume@bigpond.net.au

Adrian Lee is an unsung Australian academic hero. Warren and Marshall could not have got the Nobel Prize without him. Tom Borody told us clinicians what to do with the information that the helicobacter story revealed. So we are, all of us, particularly those in the trade, indebted to them both.

When the Nobel Prize was conferred, Adrian Lee was there in Stockholm. The recipients of the Prize recognized his vital role in what they did. He was an honoured guest of the Swedish Government for that whole week. It is true that Deakin University recognised his contribution with an honorary degree, but, for most Australian scientists, his name is not known as it should be.

Our university offices were only one floor apart. When the cryptosporidium scare was rampant in Sydney, he advised me against worrying too much. After all, kangaroos and wallabies were living in the water catchments and were depositing *cryptosporidia* every day — and no-one was ailing. However, his good advice did not satisfy my daughter, who continued to boil drinking water for her baby.

Peptic ulcers were an enormous problem sixty years ago. Our medical and surgical wards were full of ulcer disease. Our patients were suffering. Our surgical lists were full of the ill effects of peptic ulcers, sometimes urgent, sometimes elective. And we worked to a wrong paradigm — we believed that

peptic ulcers were the result of an imbalance between acid and protective gastric mucus.

We were wrong. Warren and Marshall got the Nobel Prize for proving us wrong. They could not have done what they did had Adrian Lee not been there to help. Today there are few peptic ulcers and Tom Borody's treatment fixes those.

As you all know, a strong statistical correlation does not, of itself, establish a causal relationship. Robert Koch put out his famous postulates in the second half of the nineteenth century to relate diseases to the organisms which caused the diseases, and his postulates guided scientists, like those described tonight, throughout the twentieth century. Today we use nucleic-acid-based microbiological detection methods, and Fredericks and Relman have suggested seven new criteria for establishing microbiological causation.

But Warren and Marshall had to satisfy Koch's postulates. It might be worthwhile just reminding ourselves of what they were. First, the microorganisms had to be found in organisms with the disease but not in healthy organisms. Later this condition was dropped because of the existence of carrier states. Second, the microorganisms had to be isolated and grown in culture. Third, the cultured organisms had to cause the disease when introduced into a healthy organism. Fourth, the microorganisms had to be re-isolated from the inoculated diseased host and identified as being identical to the original

organism. As many of you know, Marshall himself drank *Helicobacter pylori* to satisfy those last two tests.¹

Over time there were many problems with Koch's postulates — for instance, with viral diseases — but, at the time, they worked, and Warren and Marshall wanted to satisfy all Koch's postulates, not least to convince hostile adherents to the older paradigm.

You will recall that the second Koch postulate required them to grow and isolate the microorganism in culture, while the fourth postulate required the organism to be regrown from the host in which it had caused disease. These two postulates were where Lee was critical. Here was he, an Eastern Stater to those two West Australians, but an Eastern Stater who possessed the techniques they needed for their work. So, there developed this wonderful association between Warren and Marshall and the University of New South Wales.

¹ As Adrian Lee has put it (pers. comm.): "Koch's postulates could not be covered in the early days as there was no animal model. But then of course Barry in his unique way did it by swallowing the bug. Fulfilled the postulates exactly. Given the bug, got the disease — gastritis — and then recovered the bug in culture. New Zealander Arthur Morris did it too, with more severe circumstances Arthur was pretty sick and could not get rid of the bug!!"

Thomas Borody is famous for developing the Triple Therapy for peptic ulcers. He did this in 1987. Prior to this time ulcers were cured by drastically different methods.

To have heard them both speak tonight has been wonderful and we want to thank them for what they have told us and we want to honour them for what they helped give to us all.

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2020 Royal Society of NSW and Four Academies Forum: “After COVID-19: Creating the best of times from the worst of times”

Her Excellency the Honourable Margaret Beazley AC QC

Opening Address

“Bujari gamarruwa
Mudgingal
Babana
Gamarada
Gadigal.”¹

As Patron, I welcome all members of the Royal Society and the four learned Academies as you examine “After COVID-19: Creating the best of times from the worst of times,” as this 2020 Forum is titled. I especially welcome our university students who are represented at this Forum. Your voices are important to this conversation.

In a year where just about every possible analogy has been used to describe the impact of COVID-19, likening it to a war, a hidden enemy, a year like no other, and that literary reference to “the worst of times” from the indefatigable Charles Dickens, there is perhaps one observation, which more than others, captures where we are at the moment: “nobody knows how the story ends.”² Indeed, scientists are unsure whether this particular story does have an end. We do know, however, that it has had, is having and will continue

to have consequences. We also know that the negative consequences have not fallen equally on the various sections of our community.

In the research article *The Impact and Implications of COVID-19: An Australian Perspective* (O’Sullivan et al., 2020), the authors posited that: “People who were already poor, unemployed or underemployed, with high levels of existing debt ... or facing existing difficulties with access to health and social services, and people with disabilities, were likely to be further marginalised.” We also know that mental health has been of significant concern and that isolation has been a particular problem.

At the community level, Philanthropy Australia has pointed out that “The economic realities of COVID-19 are threatening the existence of not-for-profit organisations and charities” and their capacity to respond. As demand for their services increased, the pandemic diminished their ability to fund-raise.³

On the positive side, I have found people, both personally and within organisations, thinking and re-thinking about what is important to them and those around them; what things they would want to keep arising

¹ Michael West, Cultural Officer, Metropolitan Local Aboriginal Land Council. Translation: “Good day, men, women and friends/comrades.”

² <https://time.com/5779872/coronavirus-ebola-news-coverage/>

³ <https://www.philanthropy.org.au/tools-resources/news/australian-philanthropys-response-to-the-covid-19-crisis/>. Also quoted in O’Sullivan et al. (2020).

out of the COVID restrictions; what things they would do differently in the future. As the Artistic Director of one of our creative festivals said: “I feel that COVID has given the introverted part of my brain time to think.” He was, of course, talking about the time to think and re-think creatively and, indeed, about creativity itself.

Karl Schwab, the founder of the World Economic Forum, summed the position up well when he said: “Deep, existential crises favour introspection and can harbour the potential for transformation ... People feel a time of reinvention has come.”⁴ These words echo what John F. Kennedy had pointed out in 1959 when he said: “When written in Chinese, the word ‘crisis’ is composed of two characters — one represents ‘danger’ and one represents ‘opportunity’.”⁵

This period of time offers us the chance to press the re-set button; to make this a time of re-calibration and reinvention; to think how we can “build back better,” a term

that has been used by leaders from Jacinda Arden to Joe Biden and organisations from the OECD to the United Nations. To do this, we will need to draw on the strength, the ingenuity and the creativity of each sector of our community.

In the best Royal Society tradition of “omnia quærite” (question everything), this year’s Forum provides a unique and fertile environment — in the words of one of our esteemed speakers, Dr Genevieve Bell, to “create a little bit of room to imagine other interesting possibilities of how we want to be (and) who we want to be.”⁶

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⁴ <https://www.afr.com/world/europe/when-will-things-get-back-to-normal-never-says-davos-founder-20200714-p55br2>

⁵ John F Kennedy Speech: United Negro College Fund, Indianapolis, Indiana, 12 April 1959.

⁶ Dr Genevieve Bell, Reshaping Australia dialogue, in *Australian Financial Review’s* Recalibrating Society series: <https://www.afr.com/companies/financial-services/recalibrating-society-in-a-disrupted-time-20200804-p55icq>



Immunity from history: What can we learn from collective responses to crises?

Peter Hobbins

Australian National Maritime Museum, Sydney, Australia
Department of History, The University of Sydney, Sydney, Australia

Email: peter.hobbins@sea.museum

Abstract

History is often evoked as a form of immunisation, as though prior exposure to a threat should protect us from its recurrence. The galloping crises of 2020 were no exception, with historians invited to offer guidance in the face of “unprecedented” challenges to our social and environmental fabric. But what illumination, inspiration or consolation can we meaningfully draw from the past? In revisiting the history of environmental, medical and technological hazards, this paper explores the histories of snakebite, aircraft accidents and epidemics. Did common threads unite efficacious responses to these challenges? Did they offer partial immunity from recurrent threats, or merely the illusion of protection? And what was the most effective scale of intervention — local, national or global? Moreover, how might we translate our history for the futures that we face together?

Introduction

In delivering the Anniversary Address of the Royal Society of New South Wales in 1894, Professor Thomas Anderson Stuart vacillated between commendation and lamentation.

As the Professor of Physiology at the University of Sydney, Stuart had recently reviewed the Colony’s legislation relating to public health. His task was urgent: over the preceding year, he asserted, a disease outbreak had “practically overrun the whole Colony.” Between them, Stuart surmised, measles and scarlet fever had afflicted 36,000 citizens — nearly 3% of the population. A concurrent outbreak of diphtheria in Cowra had spread to almost a third of its residents, with a case-fatality rate of 13%. Citing recent developments in the US state of Michigan, Stuart called for greater government powers of notification, isolation and disinfection

for communicable diseases. His wish would soon be satisfied by the comprehensive *Public Health Act* of 1896.

Yet in that same 1894 address, Stuart also lauded a potential technological solution. Pastoral experiments with a locally produced anthrax vaccine in over 50,000 sheep had reduced herd mortality from a predicted 20–30% to just two animals. Indicating a galloping community acceptance of the still-novel concept of acquired immunity, he also noted a widespread lay practice in districts where paralysis ticks (*Ixodes holocyclus*) were common. Rural dogs were “regularly made immune” by allowing ticks to feed until their poisonous saliva caused its characteristic symptoms. “Upon complete recovery this is repeated one or two times,” Stuart explained. “After this the dog is protected.” But if country folk eagerly immunised their animals, he lamented, few

Sydneysiders would submit to voluntary vaccination against smallpox, even though it was as lethal as anthrax in livestock. Only an active outbreak, it seemed, spurred humans to protect themselves (Stuart, 1894).

“The future will bear out the past”

In the context of the coronavirus (COVID-19) pandemic of 2020, many of Stuart’s exasperations and enthusiasms still seem surprisingly pertinent. Although veterinary experience with immunisation promised the prospect of controlling contagion, in 1894 vaccines could not yet prevent the prevailing human epidemics. Rather than urging a local research program, Stuart pressed instead for both the expansion and consolidation of public health powers in the face of alleged local negligence. “What we have to contend with is not any real opposition,” he insisted, “so much as apathy and ignorance” (Stuart, 1894).

What Stuart advocated, above all, was the preventive power of knowledge. As the outgoing President of the Royal Society of New South Wales, his address came at the end of a long century propelled by an almost unwavering faith in progress. This philosophy was embraced by many of the Society’s members, who hailed from the Colony’s academic, bureaucratic, pastoral, mercantile and ecclesiastical elite. While many were gentlemen of learning rather than active investigators, they shared a positivist faith in the merits of accumulating empirical evidence to guide their predictions and their actions. Furthermore, they “recognised the need to educate or inform the broader public about the achievements of science” (Tyler, 2010).

Counted amongst the sciences was history. Indeed, one of the first acts of the nascent Philosophical Society of Australasia in 1821 was to erect a tablet to James Cook and Joseph Banks on Botany Bay’s southern shore, a spot that “once saw them ardent in their pursuit of knowledge” (Smith, 1882).

History was seen to offer both personal inspiration and precautionary information. Published throughout the two decades after Cook and Banks landed in Australia, Edward Gibbon’s *The History of the Decline and Fall of the Roman Empire* delivered a prophylactic tale against imperial dissipation and hubris. Its first volume was issued in 1776 — the very year that Britain’s American colonies declared their independence (Gibbon, 2005).

The consequent century of revolutions witnessed the emergence of diverse theories that sought to explain the operation and value of history in positivist terms (Burrow, 2009). In its initial usage, the very term “revolution” pointedly implied a circular view of the past, of history returning to its point of origin. Yet in a century captivated by Progress with a capital “P,” the data of history was increasingly invoked to advance society to new heights.

Here, however, a fundamental dichotomy emerged. In 1859, Charles Darwin depicted natural history as a process of incremental adaptation, an endless struggle against eternal environmental change (Darwin, 1860). Writing in the same epoch, Karl Marx argued instead that historical evidence could serve teleological ends. For Marx, the deep patterns of the past indicated how humans might actively intervene in history to attain a state of perfect social organisation (Marx, 1906).

Although it profoundly simplifies the depth and diversity of subsequent meta-historical debate, these two positions have tended to dominate the ways in which non-historians interpret narratives of the past. History either provides object lessons in how to avoid repeating our predecessors' errors, or it reveals entrenched structures from which we might model possible futures. "There need be little doubt but that the future will bear out the past," wrote Colonel Hubert Foster, Director of Military Science at the University of Sydney in 1914 (Foster, 1914). With exquisite irony, the release of his book *War and the Empire* was unexpectedly delayed by the outbreak of a global conflict that was later — if briefly — named "the war to end all wars."

For historians, too, there is an ever-present imperative to argue for the heuristic value of our discipline. "A poverty of disaster memory is convenient for some, but a tragedy for most," writes historian of technology, Scott Knowles. If we fail to systematically scrutinise past calamities, he urges, "others will do it for us without the perspectives offered by the long view of history, namely that risk-taking is no accident and disasters are never truly unexpected" (Knowles, 2014). But, as Thomas Anderson Stuart understood, knowledge alone is insufficient to overcome inertia. Thus both historians and non-historians face the same hermeneutic challenge: how can we operationalise pragmatic insights for tomorrow from a world that no longer exists?

Immunity from history?

In this paper, I propose a variant reading for the instrumental value of history. I suggest that history is often perceived as a form of acquired immunity. Rather than being

merely instructive, knowledge of the past may prove actively protective. As with tick poison, historical patterns represent both a threat and a potentially efficacious agent for prophylaxis. History may be salutary. Appropriately dosed, it stimulates proactive defence against the recurrence of unhealthy developments. When properly administered, repeated exposure further bolsters this immunity from history.

But can the past truly inure us to the future? And is the protection it affords only partial, or is it truly prophylactic? The following case studies consider three examples drawn from Australian science, technology and medicine. I consider the problems of snakebite, aviation accidents and epidemics in order to explore when, how and why we might productively apply this novel analogy. I then conclude by suggesting whether the concept of immunity from history offers false hope, or a constructive framework for planning ahead.

Shaping snakebite remedies: novelty versus inertia

It took the European colonisers less than two decades from 1788 to realise that they had little to fear from Australia's apex predators — at least on land. Neither the dingo (*Canis lupus dingo*) nor the thylacine (*Thylacinus cynocephalus*) threatened to eat, maim, trample or gore humans in the manner of big cats, wild canids, bears or pachyderms on other continents (Maglen, 2016).

Over those same two decades, however, the new arrivals became increasingly alarmed about Australia's indigenous serpents. At first they had been dismissed as innocuous, but by 1810 snakes were widely seen as the deadliest creatures in the antipodes. Although they rarely paid heed to the

natural knowledge and healing systems of Aboriginal people, the settlers shared a similarly diverse range of ideas about the danger posed by snakebite — and the most efficacious means of treating it. Throughout the nineteenth century, common settler remedies included one or more of the following: cutting the bite site, sucking out the venom, exploding gunpowder in the wound, tying a ligature, forced exercise, flagellation, smelling salts, electrical shocks, folk antidotes or imbibing copious quantities of stimulants — especially brandy (Hobbins, 2013).

By the 1850s, envenomation and its treatment were subject to the emerging scientific mode of medical inquiry. Members of the Philosophical Society of New South Wales were foremost in pursuing such explorations, publishing systematic studies and speculations in the predecessor publications to this journal (Roberts, 1858¹). Yet many of their fellow practitioners sought to guide future treatment by publishing individual case histories — isolated anecdotes that largely lacked any consistent theory or systematic analysis.

From the late 1860s, the introduction of two injectable snakebite remedies helped to reshape the practice of Australian medical science. First came the intravenous injection of ammonia, followed by the subcutaneous administration of strychnine. Up to a hundred case reports for each were cited to extol the benefits of injecting these notorious poisons. Both individually and collectively, such cases provided the reassurance of clinical history in the pursuit of medical modernity. Despite their widespread adoption by doctors and laity, however, both remedies were ultimately discredited by two newly ascend-

ant biomedical technologies: health statistics and animal experimentation (Hobbins, 2017).

During his 1894 address, Stuart confirmed that these emergent approaches had effectively overturned centuries of dogma founded on the testimony of the practitioner. “It is only by ascertaining the physiological action of the venom as it affects the different organs and parts of the body,” he stated, “that a rational method of treatment will be definitely arrived at” (Stuart, 1894). Indeed, his University of Sydney colleague, physiologist Charles Martin, simply dismissed the 400-odd previous Australian publications on snakebite. Instead, he conducted a lengthy program of laboratory studies into the venom of the red-bellied black snake (*Pseudechis porphyriacus*). It was so thoroughgoing that Martin earned the 1895 medal of the Royal Society of New South Wales (Martin, 1895).

Martin also led the new field of experimental immunology, developing the first antivenene (antivenom) for Australian snakebites in 1897. Although highly targeted and efficacious, the technical complexity of antivenenes created a clinical quandary. There were no local serum facilities suited to their production, nor did networks exist for their distribution, storage and administration. Thus, having dismissed the historical experience and expertise of his predecessors, Martin left local practitioners with few alternatives but to fall back upon superseded remedies. For instance, while the first commercial antivenene finally entered the Australian market in 1930, major hospitals continued to offer strychnine injection for snakebite into the 1950s, even though it had been condemned half a century earlier.

¹ Read at the meeting of 14 October 1857, of the Philosophical Society of NSW. [Ed.]

“We should beware of privileging the novel,” cautions historian of technology, David Edgerton, as history suggests that novelty rarely trumps the inertia of the everyday (Edgerton, 2010). While snakebite treatments evolved, Australian clinicians remained alert to the faddish cycles of medical innovation. By retaining a diverse armamentarium of prior remedies, they insured their practices against the failure of the latest advances. Oftentimes, patients also insisted on older treatments, riding out the rhythms of change.

Iterative immunity: avoiding aviation accidents

Novelty, nevertheless, can shape history. Among the most instrumental adopters of the “history-as-lesson” mantra is the aviation industry. Both in civilian and in military contexts, an overt and ubiquitous justification for reviewing historical crashes is “to provide a reminder of the circumstances of those losses and see how the lessons can be applied today” (Directorate of Defence Aviation and Air Force Safety, n.d.). Paradoxically, the risk landscape of flight is regularly depicted in Darwinian terms: “Safety is not a utopian state which can be reached, it is a continuing battle against ever changing threats,” remarks industry expert Graham Braithwaite (2001).

One result is a voracious appetite for accident reports configured not as human tragedy, but as pedagogy. Another is the sophisticated forensic framing of investigations, which seek to integrate technological, environmental, systemic and human factors into a complex causality matrix. But as historian of science Peter Galison argues, drawing salutary lessons from accidents is often confounded by the dialectic between blaming specific artefacts, circumstances

and decisions, and diffusing causation across systems, environments and historical trajectories (Galison, 2000).

Nevertheless, as Figure 1 suggests, the cumulative effect of regulations, operations and investigations has drastically reduced Australia’s fatal accident rate across diverse forms of aviation, especially since the 1950s.

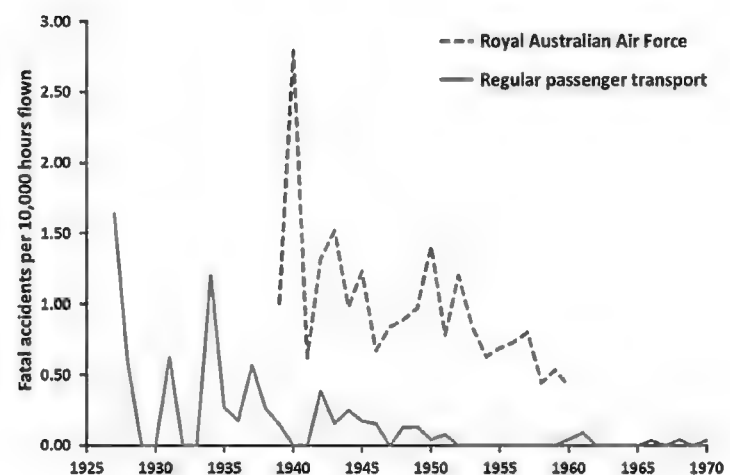


Figure 1: Fatal accident rates versus year for military and scheduled passenger aviation in Australia, 1925–70 (unpublished data).

This proud and hard-won historical record amply illustrates the value of a virtuous cycle, in which flaws are identified via analysis of previous accidents and incidents. Shortfalls are circumvented in later design, maintenance, recruitment, training, operating and oversight systems. The survival of Qantas flight QF32 after an uncontained engine disintegration while climbing out of Singapore in 2010 is a case in point. Despite the accident being traced to inadequate quality control during engine manufacture, the Airbus A380 landed safely, in part because its design incorporated survivability guidelines developed after prior engine disintegrations in the 1970s and 1980s (Australian Transport Safety Bureau, 2013).

Such forensic incision can prompt its own perils, however. For example, leading safety investigator Alan Hobbs sought to debunk an industry axiom: that rising tech-

nological reliability drives the proportional blame for accidents increasingly toward human factors. His analysis compared 100 Australian aircraft crashes over 1921–32 with a cognate dataset published in 1996. Noting an almost identical proportion of accidents attributed to humans for each period (68% *vs* 72%), Hobbs contested the depiction of human factors as an escalating and urgent “last frontier” in complex sociotechnical systems (Hobbs, 2004). However, my own published and unpublished accident data reveals a marked variability over time. Based on archival records spanning 1921–75, the fault ascribed to humans see-saws between 31% and 85% for both military and civilian aircraft crashes (Hobbins & Roberts-Pedersen, 2019). By taking such a longitudinal view, the presumed continuities of history seem shaky indeed.

Finally, proposes technology scholar John Downer, a paradoxical driver for historical improvements in aviation safety is the inherent conservatism of the industry itself. By copiously imbibing history, he asserts, aircraft designers “believe in progress, but only by consecrating traditions and building on the hard-earned wisdom of their predecessors” (Downer, 2017). The inoculation of the past, if we may call it that, continues to engineer a conservative cycle of virtue.

Viral history: eradicating epidemics

My third and final historical case study considers contagion. In the COVID-19 epoch, historians have been especially in demand. We have been asked both to recapitulate the social, political and economic impact of past pandemics, and — rather more hesitantly — to prognosticate about the post-COVID future. In fact, history has been a major component of pandemic planning over the last century.

If Stuart fostered aspirations for alleviating epidemics, he had precious little positive history to guide him. Since his arrival in Sydney in 1882, notable improvements had been made in the city’s sanitation, including its water supply, sewerage, refuse collection and the removal of noxious trades to the outskirts (Coward, 1988). However, as he noted in 1894, multiple transmissible diseases flowed readily across the Colony, even as smallpox vaccinations remained a rarity. Curiously, Stuart ignored both the recently passed “Russian” influenza pandemic and the creeping spread of bubonic plague around the Pacific and Indian Ocean rims.

Pestilence in the past had typically abated as a result of uncontrolled contagion, hasty containment or calamities such as the Great Fire of London. For Stuart, as for many of his contemporaries, immunisation represented an almost unparalleled upheaval that might alter the mode, scale and politics of prevention. The sole human exemplar to guide its adoption was vaccination, first introduced a century earlier in 1796. It entailed inoculation with the relatively innocuous cowpox, to reduce the danger of suffering from smallpox. Vaccination had, in turn, superseded the far riskier previous practice of variolation: inoculation with a mild variant of smallpox itself (Bennett, 2020).

In reviewing the anthrax immunisation data in sheep, Stuart also faced the long and fractious history of smallpox vaccination in the Colony. Unlike several other Australian colonies and Great Britain, New South Wales had never mandated compulsory vaccination. One result, he noted, was the limited popular impetus for protection unless an epidemic threatened. Yet throughout the nineteenth century, smallpox remained a slow pandemic, in part because of the erratic

global adoption of vaccination (Bhattacharya & Brimnes, 2009). Even when the disease circumvented Sydney's quarantine system in 1876–77 and 1881–82, the rise in metropolitan vaccination rates was merely ephemeral. Both outbreaks were instead overcome by vigorous maritime and municipal quarantines. These measures were predicated on drastically increased powers for the city's centralised Board of Health and — for the first time — the enforced confinement of citizens (Hobbins, 2017).

As a prominent intellectual and an advocate for public health, Stuart therefore faced a historical dilemma. In the context of concurrent epidemics of measles, scarlet fever and diphtheria, should he place faith in the true “herd immunity” against anthrax recently proven in sheep, or urge a further extension of medical policing powers? Each path would potentially diminish the liberties that colonial citizens took for granted. In this context, major advancements in medical technology and authority hardly bespoke “progress” to Sydney's poorer residents, as they had protested to a Royal Commission into the 1881 smallpox outbreak (Street et al., 1882).

Stuart's message largely reflected his audience. He asserted that improving public health was “distinctly a poor man's question.” Yet in proposing laws to enable the compulsory notification and prevention of transmissible diseases, he presumed that “I do not suppose there is a man in the room who does not assent” (Stuart, 1894). The men in the room were, of course, members of the Royal Society of New South Wales. Stuart himself was not a politician, bounden to the votes of an increasingly enfranchised male populace. But law-making required champions in Parliament, and many Members in the audience heard his entreaties.

Balancing the frustrating history of smallpox vaccination against the conspicuous successes of compulsory surveillance and detention, Stuart recommended regulation rather than research. Immunisation might hold prophylactic promise, but it did not offer the certitude of the recent past. That past itself promised two forms of immunity. The first was the pragmatic knowledge that such measures had demonstrably defeated disease several times in recent memory. The second was political immunity from protest, founded on an appeal to history as the ultimate arbiter of authority to speak for the future.

Threats and threads

History is operationalised every day across diverse fields of human endeavour, from facial mask wearing to pandemic planning. Its instructive value is primarily perceived via past prototypes or parallels. Studying history is frequently justified by positioning it as a source of verifiable observations — data that can shape our conscious, rational decisions about future choices and their consequences.

But as I have suggested in the three examples above, the concept of immunity from history also entails an attitudinal element. It presumes a degree of subconscious absorption of the past that may protect us into the present. Both the pattern and the prototype models of history have shaped professional cultures, industry standards, political processes and our normative assumptions about which paths are possible, or desirable, or just. It need not be overt to be salutary, but as with any form of tradition, it can readily become reactionary.

If our aviation safety record is one indicator, an entrenched culture of conservatism is not necessarily a retrograde development. The very accountability

of posterity encourages a precautionary approach. Yet even well-intentioned examples can prove problematic if they suggest a stability not borne out by the messy trajectories of history. Australia's history of snakebite treatments also illustrates the unhealthy allure of prior practices when progress proves problematic. And Stuart's patrician attitudes toward the "poor man's question" of eliminating epidemics were shaped as much by the previous political success of public health interventions as by the promise of shaping new knowledge.

Sojourning across scale is also intrinsic to seeking immunity from history. Individual exposure is critical, but the collective response shapes its cumulative impact. Industries and communities comprise individuals, whose daily decisions are often drawn from personal and proximal history. The diagnostic process in medicine, for instance, commences with taking an individual history. But both the prognostic and therapeutic options are guided by the cumulative histories of prior patients.

At both conscious and unconscious levels, models and examples drawn from history remain critical to everyday decision-making across science, technology, medicine and the humanities. But fostering an immunity from unhealthy precursors requires critical analysis of both our historical evidence and the stories it feeds. Our urgent challenge for the post-COVID world lies in credibly communicating those collective narratives — at least where we concur that history may be salutary.

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#COVIDTIMES: Social experiments, liminality and the COVID-19 pandemic

Genevieve Bell

College of Engineering and Computer Science, Australian National University,
Canberra, Australia

Email: Genevieve.Bell@anu.edu.au

Abstract

On the 22nd of March 2020, the Australian government announced Stage 1 restrictions in response to the global coronavirus pandemic (Johnson and Smale, 2020). Since then, numerous nation-wide measures have been implemented in an effort to control the rate of transmission and minimise the pandemic's negative impact on the Australian people and the economy, ranging from lockdowns and stay-at-home orders to border closures and extensive contact tracing systems. As a growing body of research emerges exploring the efficacy and consequences of these strategies, there is an opportunity to reflect on their social and cultural impacts. In this paper I propose two analytical lenses through which to understand these impacts, framing the pandemic firstly as an (unplanned) social experiment which has transformed and illuminated our relationships with digital technologies, and secondly as a liminal moment and a shared set of social experiences.

Introduction

On 11 March 2020, the World Health Organization (WHO) declared COVID-19 a global pandemic; that is, there was the worldwide spread of a new disease. The last such declaration had been made on June 11, 2009, with “swine flu,” or the H1N1 influenza virus. That declaration, in turn, drew on lessons learnt from the SARS outbreak in 2002. Yet very little of the world's experience of the 2009 pandemic, or indeed the various outbreaks of SARS (2002–2004), MERS (2012), and Ebola (2014–2016) would prepare us for what would happen next — though the blueprint for how to handle the COVID-19 pandemic owes much to prior outbreak management, including quarantines, border closures and selective quarantining. The WHO's 2020 declaration triggered action at a speed and scale that was new and startling.

The pandemic has disrupted everything, from the global flow of goods and services to the actions that individuals can take in their daily lives. The estimated economic impact on both Australia and the world at large is significant, with growing unemployment and uncertainty about the future of the globalised economy, and with some countries expected to enter a recession in the next year. Throughout the first year of the pandemic, governments all over the world enacted a range of measures to mitigate and control the impact of COVID-19, including border closures, travel restrictions, stay-at-home orders, economic stimulus packages, and wide-sweeping public health measures, including contact tracing technologies and processes, mandatory masks, and quarantines. Many of these measures were enacted repeatedly, as the virus spread and mutated and as our social systems attempted to adapt and

manage in response. Strategies around containment, management, and elimination have been adopted, rejected, or adopted anew, and the complexities of mass vaccination campaigns have roiled many nation states.

Nearly a year after COVID-19 was first declared a pandemic, there have been over 114 million cases and over 2.5 million deaths (WHO, 2021). The human toll and impact will continue to unfold for years, touching everything from health to education and employment; there remains little to no clear consensus about how or when this pandemic might end, or about how daily life might look in its aftermath.

There will be many accounts written about this period and about its consequences. However, even now, as we remain in the midst of the pandemic, there is significant insight to be gained from the ways in which we are experiencing it, collectively and individually. How we make sense of this moment, and how it might inform what comes next, in terms of new practices, values and even rules, feels generative. Likewise, an analysis of our passages through the pandemic could help illuminate possible opportunities for meaningful social, political, institutional, and individual transformations.

Australia and COVID-19

By early April 2020, more than half the world's population was in some form of state-sanctioned lock-down (Kaplan et al., 2020; Sandford, 2020; Storrow, 2020; Woods, 2020), and the use of stay-at-home orders and other forms of restrictions have continued globally ever since, with some countries closing their borders completely and others entering into the second and third periods of city, region and state-wide lockdowns.

In Australia, our first stay-at-home orders came in effect late March, when the Australian government announced that all Australians were to stay home, and we would, at a nation-wide level, attempt to “flatten the curve” (Johnson & Smale, 2020). There were four categories of exceptions to the stay-at-home mandate: health care; shopping for food and basic supplies; exercise; and essential jobs. The logic behind the stay-at-home orders were two-fold: slow the rates of transmission, and make it possible for the nationwide public health systems to prepare for a predicted inflow of patients.

In early May, the co-ordination between the federal and state governments in Australia gave way to a patchwork of responses and restrictions that have persisted ever since, including state border closures, travel bans, and quarantines. These responses have included a variety of stay-at-home orders, ranging from short, sharp closures, “circuit breakers” (Adelaide, November 2020; Perth, Brisbane, January 2021; Melbourne, February 2021), to longer and more protracted restrictions, including an unprecedented 111-day stay-at-home order in Victoria which, combined with a nightly curfew, restricted mobility, and border closures (August–October 2020).

As a result of these interventions and continued travel restrictions, border closures and aggressive public health measures, Australia has recorded only 29,000 cases and a little over 900 deaths since the first case appeared in Australia in January of 2020 (Australian Department of Health, 2021). There will be much written about the economic impact and the various government mechanisms implemented to ameliorate the worst harms here in Australia. Likewise, the social and cultural impacts which have

been far reaching, offer much upon which to reflect and learn. In this paper, I want to offer just two possible avenues of analysis of the social and cultural impacts here in Australia: the pandemic as (unplanned) social experiment; and the pandemic as liminal.

The pandemic as social experiment

The immediacy and scale of the various stay-at-home orders here in Australia created massive social change in a very short time. From the initial nationwide stay-at-home orders in March 2020, to the various state and city restrictions, one way to think about the pandemic is as a series of significant social experiments here in Australia. Of course, these “experiments” were unplanned, frequently ran without a control group, and were certainly not something to which we, as participants, had anything resembling informed consent or an ability to decline to participate. That said, there is much we can learn from the impact of the pandemic on our daily lives, and especially regarding the role of technology in our daily lives. The lessons we could draw from this period might help inform public policy, regulation, and standards, as well as future state, national and private investments in everything from infrastructure to training.

Here are just five areas in outline, related to technology in our daily lives, we could choose to examine further:

Remote work

The feasibility of remote working was abruptly tested in late March and early April of 2020, with organisations small and large transitioning to a remote workforce within days or weeks. This has created new ways to work, and tested underlying infrastructure, technical literacy, and availability of equip-

ment. It made more visible long-standing social and economic inequities, especially around gender (Johnston et al., 2020). What quickly became clear was remote work was more than just giving someone a webcam on a laptop: it meant changing the nature of how an organisation functions, the purpose of meetings, and organisational processes and structures, including how new employees are on-boarded, and teams are cultivated.

Online education

Making online education successful is more than just putting your PowerPoint slides online or settling a student in front of a laptop. During the pandemic, the efficacy of online, digitally enhanced, and/or remote education learning experiences has been tested with a range of student demographics (from primary and secondary school to university, to professional training). Students have encountered new forms of learning, and the changes have revealed complex layers of infrastructural, pedagogical, social, and familial challenges, as well as reinforcing some of the oft-encountered challenges for regional and remote communities (Armour et al., 2020), and revealing new forms of tacit labour in the home as parents became teachers’ aides and technical support.

Telehealth services

The pandemic has seen the Australian Government introduce temporary measures to increase the scope of telehealth coverage under the Medicare Benefits Scheme (MBS) to cover the entire population due to its effectiveness in triaging and monitoring COVID-19 cases — a quality already demonstrated in countries such as Singapore and South Korea. An unforeseen consequence of this has been greater insight into the poten-

tial benefits of telehealth, and it appears that government moves to roll back these measures are already meeting resistance from medical practitioners (Maguire, 2020; Hunt, 2020; Seselja, 2020). After all, being able to see your doctor at the appointed time without having to think about parking or worrying about how you are going to manage your children or how you are going to get into the office seems like a positive step.

Online shopping and payments

The closure of brick-and-mortar stores driven by pandemic-related public health measures such as social distancing has been accompanied by a rapid uptake in Australia's traditionally laggard e-commerce industry, with 5.2 million Australians shopping online in April 2020 — the highest number ever recorded at the time, and 31% higher than the 2019 average (Australia Post, 2020; Mortimer et al., 2020). This has put pressure on delivery systems and payments systems, and raises questions about the future of certain kinds of physical spaces. This online shopping boom has also created a wave of new data, unexpectedly impacting algorithms that help determine supply chains, goods, and future purchases.

Australia is already well-known for its high adoption rate of contactless “tap and go” payment methods, and COVID-19 has only encouraged this trend by transforming contactless payment from a convenience to a hygiene necessity. This continued move towards a cashless economy has catalysed discussion about the operation and equity of our existing cashless infrastructure (Letts, 2020; Collett, 2020).

Data privacy

The trade-off between safety and privacy has become very real, with the need for rapid, accurate contact tracing to help contain the spread of COVID-19, and the use of digital technologies and data to help in those efforts (Bell, 2020; Bell et al., 2020). The public debate around the use and efficacy of the COVIDSafe app made it clear that issues of privacy, trust and data collection remain sensitive ones in Australia. The rapid proliferation of state-based, commercial and local check-in mechanisms have unfolded with considerably less debate around data use, security and trust, but have nonetheless continued to thrust these issues into the spotlight. The nascent debate about a “vaccination passport” again proposes to bring these issues to the fore (Bell, 2020; Hern, 2021).

From data collection to action: next steps?

It is not yet clear which of these unintended experiments, and the many others that are ongoing, will most profoundly change us, and which will fade in a post-pandemic recovery. However, all these unplanned social experiments and their results are revelatory for how we might design a post-pandemic Australia. Clearly, during this period, we have experienced changes in how we use, think, and feel about digital technologies. Are these trends and opportunities revealed during the COVID-19 pandemic ones we could amplify or accelerate, or that we could remediate and fix for good?

As with all good experiments, even the unplanned ones, there comes a moment to move from data collection to action. While the pandemic is clearly still shaping Australian daily life, there are lessons we can

draw from the first year that could inform both public policy and commercial activity, especially regarding the importance of robust data, information and communication networks and equity of access to the same. Likewise, it is again clear that the availability of networks and equity of access must also be accompanied by significant investment in the tools, processes, security, and skills necessary to successfully utilise those networks.

The pandemic as a rite of passage

During the arc of the pandemic so far, we have variously come out of homes, gone back into homes and closed, opened, reclosed, and reopened all manner of social and commercial enterprises, as well as city, state and national borders. How would one start to talk about these experiences beyond the personal narratives? Are there ways of thinking about the pandemic as a structural social moment? Perhaps our experiences of the pandemic could also be understood as a set of shared social experiences, not just experiments. Through this lens, we might reflect on the pandemic as a journey, or as a way we have occupied time and space over the last twelve months, and in particular the ways in which these experiences of time and space are unlike those which came before (Bell, 2021).¹

At the turn of the last century, the Belgian anthropologist Arnold van Gennep wrote about the ways in which different cultures structure their movements through time and space ([1960] 2019): how

we, as humans, make passages through the world. He was particularly interested in how such passages through time and space could have a common ritual structure, and what the nature of those structures might be. In articulating his theories around such rites of passage, he also articulated a time and space in between. He called this *liminal*, or *liminality*. He, and his followers, would define it as having the quality of ambiguity or disorientation, the middle moment between what was and what will become (Turner, [1969] 2008: 94). He would also go on to write about the rites and rituals that both begin and end a period of liminality, rites and rituals of separation and re-incorporation (Van Gennep, [1960] 2019: 21). This feels like one way to think about, or theorise, our experiences of the COVID-19 pandemic. Liminality, as a way to describe the moment between moments and the places between places, is a concept that seems to resonate with the Australian experience of the pandemic (Bell, 2021).

This theoretical frame seems especially evocative now. Is one way to approach the pandemic and to talk about its consequences to think about it as a liminal moment? And if so, what are the pieces of that liminality? During this first year of the COVID-19 pandemic, have certain spaces or times been liminal, what work were they doing culturally/socially, what work we are doing in them, and how have we transited in and out of them? Perhaps framing our experiences of the pandemic through this lens might offer a different kind of conversation.

Six liminal frames

My team and I went and looked at all the kinds of conversations people were having; the formal pieces, the governmental pieces,

¹ For many Australians, the feelings of ambiguity, unfamiliarity and dislocation pre-date the COVID-19 pandemic, given that 70 to 80 per cent of the Australian population were also impacted by drought, bushfires, and smoke (Biddle et al., 2020).

the individual responses, and we saw the outlines of six themes of this liminal stage. These threads revolve around temporality, embodiment, intermediation, mobility, relationships and identity (for a further explication, see Bell, 2021).

Temporality

The destabilising of our shared understanding of time is an obvious characteristic of this COVID-19-induced liminal moment. For many, days blurred into each other,² likewise weeks and months. The contours of time were flattened, and its cadence had new patterns: what once moved fast that now moves slow, what once moved slow that now moves fast.

Presence and embodiment

There have been transformations in ideas about presence and embodiment. At its most straightforward, the physical became virtual. We have reimagined the physical, the virtual, the digital, and the analogue, and in so doing also challenged ideas of how things do and do not move. After all, in this moment, certain forms of embodiment were seen as being dangerous, a classic hallmark of liminality. Being present was seen as being dangerous and we have actively re/calibrated our senses of our social selves to maintain “safe” distances.

Intermediation and services

How things are being intermediated has been unexpectedly hyper-visible during the pandemic. We have had to both encounter seams, borders and boundaries we had not previously seen, and then also manage them. This extended from the seams of the public and the private to the (non-)movements of

goods and services where they once did not have to move quite like that, and in the movements of people. Who has had to become a policer of these seams who wouldn't have been otherwise — parents, health-care workers, retail staff, hospitality workers, soldiers, police? Some of those seams and instances of intermediation have been long invisible and are now starkly visible — state borders would be one obvious example, likewise food supply changes. The notion of what moved and what did not, and how those things moved and having to know where they came from, is at least one form of intermediation that is now visible. Whether these seams and movements will become invisible again later is complicated. Whether we can forget them again, doubly so.

Mobility

The pandemic has been characterised by changing ideas about what could move, what should move, what should not move but did anyway, and where we had fears about things moving. This involves regulating human movement, for example negotiating the 25 kilometre border around Melbourne in the second lock-down (August 2020) and the restrictions on fly-in, fly-out workers in Western Australia mines; restricting human movement, through closing our national boundaries and thus redefining what it means to be an Australian living abroad who can call Australia home but can't physically come home; and the movement of ideas rather than bodies, where you might be part of a global community you can only see through a digital screen. These are not just questions of privilege and who is able to move, these are questions of positionality that feel as yet unresolved, but very complicated.

² Hence, “Blursday” [Ed.]

There is also, in some ways, still an emerging science concerning a whole other set of mobilities. An ongoing set of questions surrounding how a virus moves, whether it is airborne and if so, what is a safe distance from others and how can we control certain spaces, as well as how we imagine what it means to have an infected body, where they will move and how they will be treated suggests that this particular part of this liminal moment is deeply contested.

Relationships

In Australia during the early days of both the pandemic and the first lockdowns nationwide, there was a lot of borrowed language about “we’re all in it together.” That language started at a community level; a grassroots statement from households and communities wanting to articulate a degree of communal activity that was admirable and distinctly Australian. The contradistinction between the broader Australian experience of the pandemic and others — for instance the American experience — means the responsive relationship between citizens and their elected officials and their scientific and health advisors has been on display almost daily.

Nonetheless, that language of relationships, of “being in it together,” has become more complicated. Public health rules made it complicated to be together when you had to constantly consider who your relatives were, whom you were close to, who counted in your “bubble” and who was in your household. Similarly, our notions about what constituted safe connectivity and safe connection, as well as what it meant to be a social creature all fluxed.

Identity

Notions about personhood and identity, who and what we are, have been hotly contested during this pandemic period: from the “weaponizing” of demographics — for example, blaming millennials or claiming we are over protecting boomers, to the fraught use of “Karen” as a pejorative. The impact of this moment in time was felt unevenly, and that unevenness follows a set of well-rehearsed social and cultural inequities. Women have so far borne the brunt of managing home schooling, and women’s careers were more precarious and have suffered as various parts of the economy have been shuttered. What state were you in — in a geographic sense, not an emotional one — has mattered too. That our experiences were so inflected by our geographic locations suggests some very localised encounters with the liminal. Who we will be on the other side of this, as individuals, families, communities, as well as consumers and citizens, is yet to be revealed.

Exiting liminality

How and when this pandemic will end is unclear. We now have vaccines, but there are many questions regarding their efficacy, longevity and availability; for now, Australia’s national borders remain (mostly) closed. So, at least at one level, we are still, collectively, in a liminal moment. This means we could choose to contemplate how we might exit it, and in this exiting, make deliberate decisions.

Van Gennep, too, was interested in how we exited liminality, changed by our passage through it. He was particularly interested in rites of separation and rites of reincorporation — those things that individuals and

groups did to signal the end of liminality and the beginning of a new steady state. I would argue that we were plunged into this liminal moment quite suddenly, but how might we deliberately and thoughtfully structure our exit/s? How will we exit this/these liminal moments — perhaps more than once? What are the rites/rituals we will need to do — individually? Collectively? As a community? Society?

Beginning again: looking forward

“Life itself means to separate and to be reunited, to change form and condition, to die and to be reborn. It is to act and to cease, to wait and to rest, and then to begin acting again, but in a different way” (Van Gennep, 1960).

One of the reasons to approach the analysis of the pandemic from this social-centric point of view is to provide an opportunity to think about the opportunities as we exit the pandemic to (re)stabilise ourselves, our communities, and our country in new and different ways. Thus far, Australia has been fortunate in the global context of the pandemic, and our focus is shifting towards post-COVID recovery. While acknowledging that the pandemic is still at large, we are already beginning to consider and plan for a post-COVID Australia. How might we do that and what will the roles for technology be in all of this? If things have been destabilised and shaken up, would we want to stabilise them? And if so, how?

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Emerging generations and evolving intersections between technology and humanity

Dr Jordan Nguyen

Founder and CEO, Paykinetic

Email: nanette@rmbmanagement.com.au

Abstract

Biomedical engineer, inventor, TV presenter, and visionary, Dr Jordan Nguyen has lived a life of curiosity and wonder — exploring positive opportunities in science and technology, including robotics, artificial intelligence, bionics, extended reality and avatars. He believes that technology is a powerful tool that we as humans can choose to harness to create a better tomorrow. This is a precis of his talk.

As Stephen Hawking said, “Intelligence is the ability to adapt to change,” and Dr Nguyen believes the rate of technological change is the fastest we’ve ever seen, but might also be the slowest rate we’ll ever see again. Jordan Nguyen argues that we should embrace and collectively steer these changes.

He has travelled widely as a TV presenter, and so has been struck by the way younger generations are successfully dealing with challenges that no previous generation has had to deal with. He argues that, as we face future unknowns, we should seek areas of inspiration and begin with that purpose.

One area is AI: artificial intelligence. His father was using computer science (neural networks and fuzzy logic) in building a prototype robot, and “borrowed” some of Jordan’s toys when he was just 5 years old to help train the robot. This robot provided him with inspiration.

At university, he started work in robotics and AI. In his third year of university, Jordan dived into a friend’s swimming pool, hit the bottom, and damaged the muscles in his neck. Although he did not break his spine, he began exploring the options available to

quadriplegics. When he discovered how limited they were, he decided to persevere in engineering to help develop technologies for disabilities. His PhD was developing a mind-controlled smart wheelchair that used neural networks to distinguish among thought patterns (utilising electroencephalography, or EEG), in order to control the wheelchair. He has continued since to use technology to assist people with disabilities and the elderly.

He says we are too tough on failure, on making mistakes. Mistakes are what we learn from. Robots, he says, unlike some people, do not count mistakes as debits.

A motto of his is “one life, persists to improve many.” He left a position at ResMed in order to work for a charity and to develop Psykinetic, a social business attempting to put mind into action. An example of a very useful technology is software combined with eye trackers available over the counter. Connected to a computer, it tracks where the eyes are gazing and through this can control a range of apps.

Young people are no longer content, he says, to read or listen — they want other ways to learn, such as interacting with the

content, or building a virtual reality experience. For instance, in the documentary *Meet the Avatars*, shown on ABC Catalyst,¹ one sits across a virtual table, facing a virtual avatar of a loved one and having an interactive conversation.

Dr Nguyen says, “dream big, take action” — it’s brave to dream but much braver to act.

In another Catalyst documentary, *Becoming Superhuman*,² Jordan and his Psykinetic team build a headband that picks up little electrical signals from the eyes (utilising electrooculography, or EOG). This allows the wearer to control a smart wheelchair,

control home equipment, or even drive a vehicle with his eyes, even if incapable of physical movement or speech.

His 2020 book, *A Human’s Guide to the Future*,³ attempts to disseminate what science and technology is available to us, in order to collectively work towards an optimistic future and build a better world for future generations.

Finally, he proclaims, “Stand up, stand out, move forward, don’t swerve, back the forward thinkers forging futures we deserve. Be the kind of person who draws up each rising sun. Let’s stop dreaming of a better world and make one.”

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COVID-19: Transforming the way we provide health care

Dr Teresa Anderson AM

Chief Executive, Sydney Local Health District, NSW Health

Email: Teresa.anderson@health.nsw.gov.au

Abstract

This is an edited transcript of Dr Anderson's address to the Forum.

Introduction

It's a great privilege to be here with the Royal Society to share our journey in COVID-19. I would like to begin by acknowledging the traditional owners of the land on which we are meeting — the Gadigal People of the great Eora Nation. I'd like to pay my respects to Elders past, present and emerging and all Aboriginal people who are here today. One of the things that I have been most proud of in our response to COVID-19 has been our partnership with our Aboriginal communities. For us in Sydney Local Health District (SLHD), it has been the Aboriginal Medical Service Redfern, the oldest Aboriginal medical service in the land, and together we have continued to provide safe services to our community and make sure that our Aboriginal brothers and sisters have been safe during this terrible time.

And it has been a really challenging time. I'm going to talk a little bit about some boring things like governance, which has been absolutely critical to this response. The sustainability of health-care systems has been a matter of significant debate and discussion internationally. COVID-19 has reinforced that we need a sustainable and robust health system if we want to have a healthy community and a sustainable econ-

omy. Without the response of the health system, this state, this country would have much greater economic pain.

Governance

I'm going to share with you our journey and some of the things that I think have contributed to New South Wales and Australia responding in a really positive way to COVID-19. There have been many learnings. In New South Wales, it has not been luck. People keep saying to me, "Gee, we're so lucky. We're lucky we live on an island." The UK is an island. "We're lucky we live on an island that we can close our borders." The UK could have closed the borders. The fact is that we have taken a planned, systematic, risk managed approach to our response to COVID-19.

We build on terrific governance in New South Wales, governance within our health system. We have a public health system that acts as one when it needs to act as one. We have local health districts, but during COVID-19 we have acted as one. We have a strong centre and strong local health districts and facilities, and we know how to manage a pandemic.

We've had a few trial runs which have taught us the importance of having strong emergency operation centres, and, very importantly, a structure to manage the

pandemic. In NSW Health, we set up the State Health Emergency Operation Centre (SHEOC) with the leadership of Susan Pearce, the Incident Controller and Elizabeth Koff, the Secretary. You've seen our Chief Health Officer, Dr Kerry Chant, there every day with the Premier, there with the Minister of Health, giving information, giving data to our community.

That's then reflected down to a local health district. We have 15 local health districts, but, during the pandemic, we have operated as one. We've had structures that have brought us together to make sure that we're communicating with each other, that we know what's happening with each other, and that we can use the collective resources of 160,000 staff, all rowing in the one direction. At a local health district, we've reflected the same structures to make sure that each and every one of our staff feel connected to the strategy that we have.

Preparing our facilities

We've prepared our facilities, and our engineering staff have been amazing! We have been able to triple our intensive-care beds through our staff being really creative and inventive — changing the way in which we run our hospitals, creating designated COVID-19 wards so that we could rapidly expand, having “hot” and “cold” zones, and getting our equipment in — which was no mean feat. Luckily we started ordering at the end of January because we were watching what was happening overseas while still managing the impact of the bushfires on the health of our community.

We were also very focused on the basics such as having clear signage and markings in our facilities so that our staff and patients

were really clear about where was safe and where you had to have additional attention. We were focused on having enhanced cleaning, infection control processes, and the right Personal Protective Equipment (PPE) for the whole community, not just for our staff, and on ensuring that our patient flow and our pathways and our services were well prepared to manage COVID-19.

Preparing our services

And what does that mean? It meant stopping our non-urgent elective surgery, but still making sure we were looking after our patients, making sure that we put telemedicine in place so that those patients were still being cared for and monitored, cancelling face-to-face outpatients, but substituting with telehealth, making sure that we had effective visitor management in our hospitals.

Hospitals are really busy places. How do we safely look after each other? We look at how hard it is to manage the people in this room. We have thousands of people every day coming to our hospitals whom we need to keep safe. Making sure we had workforce surge plans so that if we did need to expand our workforce, we could do that quickly. We contacted Qantas when they were putting people off and said, “Hey, have we got a job for you!” And our Qantas people have been wonderful. They have really supported our staff and done an amazing job. Using our university students in new and different ways, and changing to virtual meetings — 1.6 million minutes of virtual meetings. We have the best Multi-disciplinary Team Meetings (MDTs) that we've ever had; everyone comes because it doesn't interrupt their day and it's made us safer during COVID-19.

Preparing our staff

Preparing our staff — how did we do that? We needed to focus on their wellbeing and their safety, as well as making sure that all 160,000 of our staff knew what we needed to do, making sure that our staff didn't take COVID-19 home — so we gave them all little care packs. My staff put together 12,500 care packs so that our staff wouldn't take COVID-19 home to their families.

Communication: like all of you, we are now really good at webinars, and especially the interactive ones. It is really good being able to do the Q&As with all of your staff with everybody feeling that they are able to ask questions and give ideas.

Managing the fear, worry and anxiety of our staff has been a major challenge: how terrible it has been to watch your colleagues overseas dying and know that every day that you're coming to work you are putting yourself and your family at risk. It's like a war: this virus is here and it wants to transmit. And so we needed to protect our staff, and NSW Health and the government did an amazing job in accessing the right PPE for our people and putting in place welfare programs to make sure that our staff were supported, because the pandemic impacts on your mental health and wellbeing. Many of our staff are in full PPE for all of their shifts. We have worked hard to make sure that they felt safe so that they could provide the very best care to our patients. We also implemented staff screening and visitor screening really early in the pandemic to make sure that we were protecting our patients and our staff.

We also set up Tiger Teams to support our staff and accommodation for our patients; I'll come back to that.

Managing the pandemic

Managing the pandemic itself has required us to develop new ways of working. I never thought I'd work in the airport or on a cruise ship or at a railway station, and we've been in all of those places. We have set up COVID-19 clinics and pop-ups and our contact tracing is the best in the world; everyone knows that. And that is not good luck, it's absolutely wonderful planning and a sustained investment in public health over a very long time, and NSW hasn't cut its public health units. Even when times are tough, we have not cut our public health response.

We have also established support for our people at home who are being isolated, our Special Health Accommodation (SHA) and police accommodation — we'll talk about the quarantine program in a minute — and a hotline so that we can contact people with their results. Very importantly, we have also focused on our vulnerable communities in boarding houses and public housing. In Sydney Local Health District (SLHD), we have the largest public housing towers in New South Wales. And we saw what happened in Victoria if we take our eye off the ball, so we needed to make sure that we protected our most vulnerable people.

Our vulnerable communities — homeless, social housing population

And, you know, in SLHD, we have a large population of people who are sleeping rough. I'm really proud of what the city has done to get people off the street and into safe housing during COVID-19. Why can't we do that all of the time? They should never go back. We should be doing that all of the time. We have 5,000 people living in boarding houses.

A boarding house can be a 20-room old mansion with 90 people in it, nine people to a room with cooking facilities being an electric frying pan. We are really proud that we have not had COVID-19 go through our boarding houses. We've had one person who was COVID-positive in a boarding house, so what did we do? We moved them all, everyone in the boarding house, into our SHA, did a terminal clean of the boarding house — we are very much loved by the boarding house residents now — and not one person got COVID-19 as a result of that. Making sure we protect our people in social housing is critical during a pandemic. Our plan is that if someone in social housing contracts COVID-19, we will move them and all their close contacts into the SHA. We won't lock it down.

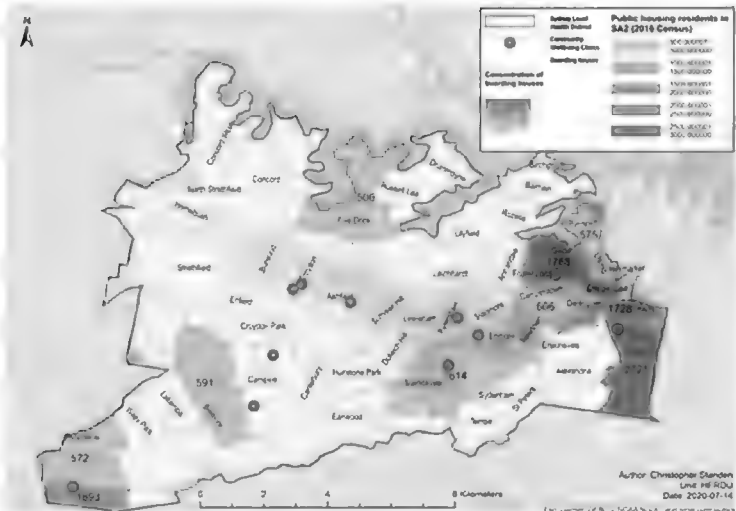


Figure 1: Rough sleeper hot spots, boarding houses, social housing and Wellbeing Clinics 2020. Map produced by HERDU 2020.

Innovations and new models of care

COVID-19 has led us to new models of care: our Tiger Teams, our flying squads. We do like a special name for our innovations. Others include rpaVirtual and the SHA. A Tiger Team — everyone knows what a Tiger Team is— and we're from the inner west Tiger Team, Balmain, you know — and it has great resonance with our staff. And the

Tiger Teams are there to care for our staff. That's their sole job, to keep an eye on our staff, to make sure that they are putting on their PPE properly, that they are donning and doffing and making sure we have clear eyes on what everyone is doing, and also providing support to our staff in unusual environments.

Our Flying Squads also went to Port Kembla to pick up the crew of the “Ruby Princess” who were COVID-positive. We had 50 of the crew in our care at the SHA for almost two months, and we had great outcomes for all of them. We were also one of the first health services in the country to undertake mask fit testing for our staff, which has now been adopted across the state.

Our Flying Squads literally have been everywhere. They have been, as I said, to the harbours, to the airports, to railway stations. And pop-ups in the community. I know more about the international and domestic airports than I ever wanted to know, but we have worked closely in partnership with the other government agencies to make sure that when the borders closed that we safely managed people who were coming into the country, and anyone who was symptomatic came to our SHA.

rpaVirtual

rpaVirtual is a new way of caring, and I have to say that when we had the idea for rpaVirtual, it was around having a better way of managing patients than coming to emergency departments, people who have chronic conditions, people who otherwise shouldn't be in hospital if they had the right care in the community.

While I was in Israel last year, I received the projections for the redevelopment of the emergency department at Royal Prince

Alfred Hospital (RPA) and it would have been the size of Canterbury Hospital, and I thought, that's not going to be very functional. So I sent a text to my staff in November saying, "We need rpaVirtual up and running by January." And I got a text back that said, "January 2021?" and I said, "no, 2020." And so our staff worked really hard to get it up and running. And without rpaVirtual, we wouldn't have been able to manage the response to the pandemic in the way that we have.

It was up and running by the 3rd of February, 2020, which was the same day, as you know, that the World Health Organisation announced the pandemic. Since then rpaVirtual has seen over 5,000 patients, both within the community and within our SHA. The feedback has been incredible. I really think the barrier for our adopting new ways of doing things is often in our own minds. Our patient experience with rpaVirtual has been amazing. It has such acceptance across all age ranges. I have to say I think I was a little ageist because I thought older people would dislike it; but in fact they love it because they feel safe and cared for and they have increasing contact with their health care providers.

rpaVirtual has managed a significant number of COVID-positive patients, now over a thousand. When we did this survey again, our COVID-positive patients felt really safe both within the community and within the SHA. We've also had a lot of people who were COVID-negative in the SHA and we've been able to support them. Their acceptance of rpaVirtual, in addition to having face-to-face contact with staff, has been quite amazing.

NSW COVID-19 quarantine program

It was great hearing the presentation this morning about quarantine because I feel like I've lived quarantine for the last six months. On the 27th of March I got a call saying, "Teresa, have we got a deal for you! We need you to go to the airport and swab anybody who's symptomatic, and if they are symptomatic, then they're going to be in your care for the next 14 days." A lot of people come through the airport and so we rapidly established the Special Health Accommodation (SHA). In SLHD we had already been providing accommodation because we have tertiary and quaternary hospitals and we have many people from rural and remote areas who come to us for care. So it wasn't a big leap, we thought, to be providing accommodation to support returning travellers in the Quarantine Program. The SHA is there to provide comprehensive health services to people who are either COVID-positive, at risk of being COVID-positive, or who have complex health needs that aren't appropriate for Police-managed quarantine accommodation.

All of the people who are in our care are patients. They all have an electronic medical record and there are very strict rules around the management of those patients. I'm really pleased to say that, although we've had over a thousand people who were COVID-positive, we have had not one instance of transmission to our staff or other patients, and that's because we have really strict protocols. We separate floors physically. We have a governance structure just like a real hospital, except it's in apartment blocks — I think I am the best customer of Meriton. I have 750 apartments and today I have 570 people in my care in the SHA. It basically functions as a very large subacute hospital.

In NSW, we are not providing quarantine in a big barn, we're not a quarantine station of the past because, although the quarantine station protects the community, it does not protect the individuals within it. We need to make sure that we look after them. Only health professionals are allowed in our SHA. Police and security monitor the perimeter. Our health workers are within the facility. And we work every day with the SHEOC, the Public Health Emergency Operations Centre (PHEOC) and the police to make sure that everyone is safe, and if anyone becomes COVID-positive within the police managed-accommodation or they become unwell, we quickly move them into the SHA or RPA Hospital and our outcomes have been amazing.

New South Wales has taken the largest number of the returned travellers: 68,000 people have come through the international border and through our quarantine program since it commenced. And, as I said, we've had over a thousand people within the SHA who are COVID-positive, 667 through the international borders, and we have had no bad outcomes with those patients. Only 17 have had to come to hospital who were COVID-positive, they have been able to be safely cared for in the SHA. We've also had over 300 patients that have come to RPA Hospital because they've had cardiac conditions or oncological conditions, and so on.

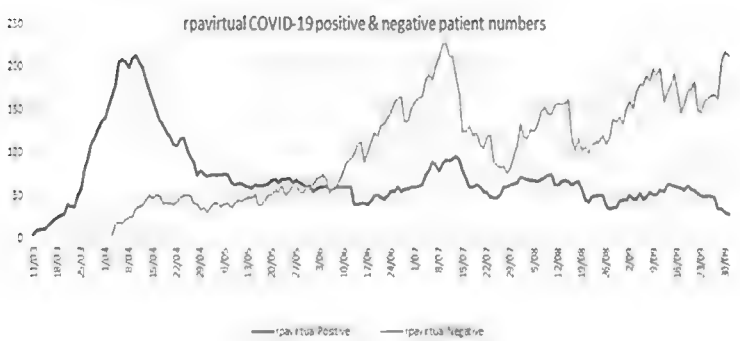


Figure 2: rpavirtual COVID-19 positive & negative patient numbers.

This is just a graph to show you our positive cases, which is the dark purple, and our negative cases. All of these people have been admitted to RPA under a COVID pathway because RPA provides the clinical support for the 5,500 people we have at any one time in hotel quarantine. When they come to hospital, they need to be managed as if they have COVID-19, and many of them do. When we think about how fast the pandemic developed and how fast we had to respond in all of these new initiatives, it tells us so much about our health system, but also about our community.

Learnings

We have gained many learnings from COVID-19:

- The importance of good strong governance: we are very lucky in NSW because we have a really mature public health service that thankfully hasn't had a restructure for ten years. We have mature and stable structures; we have a really strong public health system with a strong centre and strong local health districts that come together. And we come together not only with our public hospitals, but with our private hospitals and other government and non-government organisations. The community, if they realised, would be so impressed by the level of cooperation and collegiality, that there has been a focus on the health and wellbeing of our staff so that they could care for our patients, and a focus on communication, our leaders and our community leaders
- The importance of community engagement: there was an outbreak in Lakemba and we had our community leaders there telling people to come and get tested, helping them to feel trust in our public

health system, and it is that community engagement and partnership — not only with other government and non-government agencies, but with the community and our patients — that has actually held New South Wales and this country apart from other countries

- The use of data and evidence: it's great that during COVID-19 the community has shown that it loves evidence and data, and let's make sure that we keep being transparent and keep sharing that information so that they can actively make decisions. It's really important to trust the community with the information because that builds trust in us
- Acting hard and fast: we had an outbreak at Concord Hospital — everyone knows: it was in the paper — but we hit it hard and we hit it fast, and I put 200 people off work because we weren't sure if there had been hidden transmission, and we had no further transmission. We isolated them and we took the pain, but it stopped COVID-19 in its tracks, so being agile and being speedy, being diligent with the documentation. Being fast doesn't mean that you don't have the documentation

- And as Jordan said, listen to the ideas of our staff: all of our initiatives came from our amazing staff. They need to feel empowered, but we need to make sure that it's done in the right way that makes it safe for everyone, and making sure we continue to focus on research. And so we've had so many opportunities out of our response to COVID-19: new models of care, new ways of working, new partnerships, and new ways of caring.

Conclusion

In conclusion, I think we have done not too bad a job in our response to COVID-19, really; but I do think one of the things that the pandemic has done is that it has reminded our community of the importance of a strong public health system. Look internationally and it breaks my heart. Five hundred people died yesterday in the UK from COVID-19. To manage a pandemic, we need a public health system that is supported and nurtured. Those countries that have under-invested in their public health systems or even worse, decimated them — such as the UK National Health Service, one of the leading health services in the world, which had been decimated by austerity cuts and now they're paying the price for that. Let us all learn from this. Thank you.



Australian COVID-19 response: Lessons and future directions

Gregory Dore

Kirby Institute, University of New South Wales, Sydney, Australia
Infectious Diseases Department, St Vincent's Hospital, Sydney, Australia
Email: gdore@kirby.unsw.edu.au

Abstract

The COVID-19 pandemic has produced enormous impacts at public health, economic, and societal levels. Following the initial strategy to limit public health burden, so-called “flattening the curve”, the pursuit of an elimination strategy has brought Australia public health success and international plaudits. Initial success was driven by Federal-State government partnership, community support for restrictions and testing, and public health systems for testing, tracing, and isolating. The Victorian “second wave” in winter 2020 stretched public health systems, but community support for “lockdown” measures ensured control was achieved. Hotel quarantine for returned overseas travellers has been largely successful, although ongoing breaches and intra-hotel infections indicate the need for enhanced infection control including against aerosol transmission. Future issues include the level of vaccination required before an elimination strategy can be replaced, and whether herd immunity is achievable, or the more feasible target of “disease immunity” pursued.

Introduction

The severe acute respiratory syndrome novel coronavirus (SARS-CoV-2) pandemic and resulting coronavirus disease (COVID-19) burden has been the major global health issue of this century. The “whole of society” impact of the COVID-19 pandemic is unusual for a public health issue, albeit not unprecedented given historical global pandemics.

The first Australian case of SARS-CoV-2 infection was diagnosed on 25 January 2020, in a traveller returning from Wuhan, China, and the first locally acquired case on 2 March. Contact tracing with isolation, and a ban on non-residents entering Australia from high-risk countries (China, South Korea, Italy), were implemented between 1 February and 11 March. Subsequent measures included 14-day self-quarantine for all returning travellers (15 March), closure of borders to all

non-residents (19 March), physical distancing recommendations (21 March), closure of gathering places (23 March), and stage 3 “stay at home” isolation requirements (29 March) (Price et al., 2020). During the “first wave” of the Australian epidemic, the number of cases increased rapidly to a peak of 460 daily on 28 March, before declining to fewer than 10 per day in mid-April and late-May. Stage 3 requirements were relaxed by the end of April; by mid-May, restaurants and businesses had largely re-opened.

Initial uncertainties

A major initial controversy in relation to SARS-CoV-2 was the extent of morbidity and mortality following infection. Initial limited testing, uncertainty around proportion with asymptomatic infection, and lack of representative population-based studies made estimates problematic. Although the initial focus of COVID-19 was in Wuhan,

China, the overwhelming of healthcare services in Northern Italy in March 2020 was the first evidence of the enormous burden of severe illness. The case fatality rate (proportion of deaths among diagnosed cases) was around 5 in 100 cases, and clearly higher in older age groups. As further data emerged, a better assessment of the key infection fatality rate (proportion of deaths among all infections) was possible: a systematic review indicated around 0.5 to 1 in 100 infections, with considerable age-specific variance. For example, the estimate for a person of 80 years was around 10 in 100, but less than 1 in 100 for those under 60 years (Levin et al., 2020).

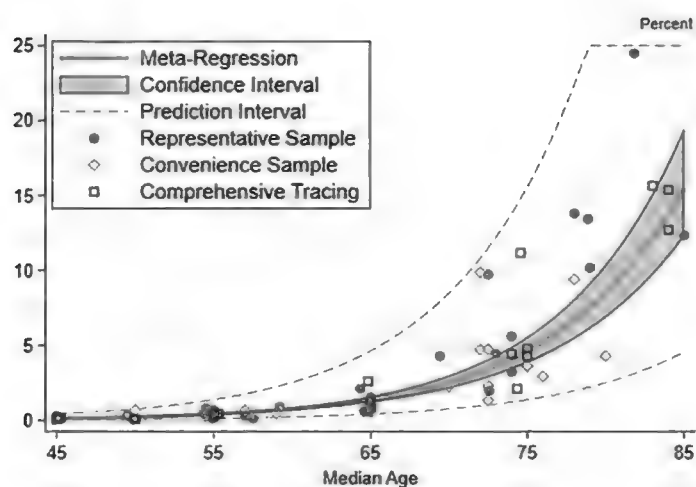


Figure 1: SARS-CoV-2 infection fatality rate (number per 100) by age.

The efficiency and modes of transmission of SARS-CoV-2 were further areas of initial uncertainty. The infection transmission efficiency factor or “reproductive number” R , a measure of the number of infected per infected individual, appeared to settle in the 2–3 range as data emerged, particularly from China. Clearly, introduction of non-pharmaceutical interventions (masks, physical distancing) has an impact in reducing the R value. On the other hand, new “variants of concern” have emerged with possible enhanced transmission efficiency.

The major modes of transmission were initially thought via respiratory droplets and fomites, thus the institution of close contact restrictions and hand hygiene as major prevention measures. As new evidence accumulated, the role of aerosol transmission has become clearer, and the associated need to consider further prevention measures: improved masking (e.g. N95); adequate ventilation for indoor spaces, even when reasonable physical distancing is maintained (Greenhalgh et al., 2021).

Australian COVID-19 response

Initial Australian Government-commissioned mathematical modelling indicating intensive care units would be overwhelmed by an unmitigated COVID-19 epidemic was clearly pivotal to adoption of major restrictions during the first wave in March 2020 (Moss et al., 2020). The strategy was to prevent the potential exponential rise in cases and a storm of severe illness, the so-called “flattening the curve” approach. These restrictions, including “stay-at-home” regulations and limitations on gatherings, had the desired effect, with cases rapidly declining by early April. In fact, by end-April the COVID-19 storm — never cyclonic — had passed and many restrictions had eased.

The Victorian second wave

The number of COVID-19 cases in Australia was low through May 2020, with several jurisdictions including New South Wales having long periods of no or very few locally acquired cases through May and June 2020. In Victoria, small numbers of daily cases continued through May, with meatworks and school “clusters” plus hotel quarantine breaches seeding major community spread by late June; “lockdown” measures

were introduced, and mandatory masking added, in early to mid-July. This “second wave” of COVID-19 cases concentrated in Melbourne, easily surpassed the combined Australian “first wave” in terms of case numbers (around 3,000 per week in late July) and deaths (around 100 per week during August).

Although other Australian jurisdictions have had short-term lockdowns and temporary measures, including mandatory masking in public, the prolonged nature of the Victorian restrictions (only eased from mid-September) clearly separates their experience from the remainder of Australia’s.

As of May 2021, Australia had reported around 30,000 COVID-19 cases (20,500 from Victoria) (Figure 2), with total deaths of 910. Over the previous six months, there had only been one death, highlighting the recent public health success.

The Victorian experience in turning around a rapidly escalating and broad community epidemic and achieving effective elimination by October 2020 is relatively unique internationally. This demonstration of effective government leadership and community action consolidated the growing realisation that an elimination strategy was achievable.

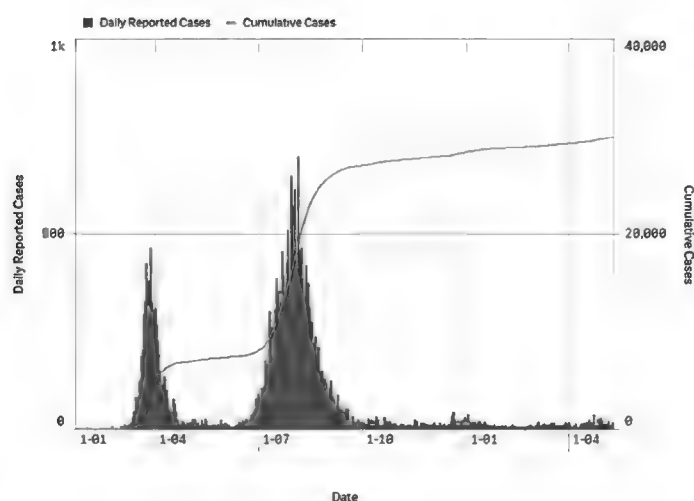


Figure 2: COVID-19 daily cases in Australia.

Australia takes on elimination strategy

Eradication of global infectious diseases has been a near-impossible task, with only smallpox on the list of human infections to achieve such a public health goal. Elimination — the reduction of incidence of infection or disease to zero in a defined geographical area or population — is clearly a lower bar, with several infectious diseases including poliomyelitis achieving this in large parts of the world. The initial scepticism around COVID-19 elimination related to the global pandemic nature of spread and inability to completely close our borders to international travel.

The demonstrations in New Zealand, Taiwan, and Vietnam that country-level elimination could be achieved, even if relatively short-lived, together with elimination success in several Australian jurisdictions led to the adoption of either an elimination strategy or “zero community transmission” strategy at state and federal levels.

Despite ongoing hotel quarantine breaches in most jurisdictions taking international travellers (largely Australian residents), there has been relatively limited local transmission of SARS-CoV-2 during 2021. The economic advantages that have followed elimination, despite occasional short-term lockdowns, have clearly demonstrated the success of such a strategy at public health and societal levels.

Lessons from the COVID-19 response

There are several lessons that should be taken from the Australian COVID-19 response to date that should shape the future response, but also have implications for broader public health responses:

- COVID-19 “holds a mirror to” public health systems and finds any weaknesses

- “*Flattening the curve*” not enough; community transmission control = health & economic benefits
- Australia has benefited from the Federal system of government, with generally impressive leadership from jurisdictional political and public health representatives
- Vulnerable populations have been protected, with some key exceptions
- Prevention is paramount, with false hope in “miracle cures.”

Future directions for COVID-19 response

Despite the clear public health success of the Australian COVID-19 response, there are ongoing challenges that will need to be faced through 2021 and beyond. The escalation of cases and deaths in India and other low- and middle-income countries is in stark contrast to ongoing COVID-19 elimination success in several countries including Australia, and the marked turnaround of high caseload epidemics through a combination of non-pharmaceutical interventions and rapid COVID-19 vaccination in United Kingdom, United States, Israel, Qatar, and other countries.

COVID-19 vaccine implementation

The development and licensing of several highly effective and safe vaccines in less than 12 months from the initial isolation of SARS-CoV-2 as the causative agent for COVID-19 is truly remarkable (Kwok, 2021).

In vaccine development, several years (often much longer) are required to develop and license, let alone implement, effective vaccines. The intense focus and investment in COVID-19 vaccination is unprecedented in science, and the variable success in implementation of non-phar-

maceutical interventions in most settings around the world placed further urgency on rapid development. Several classes of COVID-19 vaccine have been developed, including mRNA, adenovirus (chimpanzee and human) vector, sub-unit nanoparticle, and attenuated virus forms. Although different vaccine technologies have been utilised, all have incorporated the SARS-CoV-2 spike protein, which includes the receptor binding domain — key for cell binding and entry.

The failure of the University of Queensland COVID-19 vaccine, that incorporated “molecular clamp” technology to stabilize the spike protein and enhance immunogenicity, was clearly disappointing, but research is continuing to develop modifications for potential future evaluation. The “failure” was not due to a lack of immunogenicity, which was impressive in early phase evaluation (Chappell et al., 2021), but use of an HIV protein segment within the clamp element led to a small proportion of individuals developing false positive HIV antibody results, enough of a concern to halt further development.

The Australian Government has multiple COVID-19 vaccine contracts with companies, including ChAdOx1 nCoV-19 (Voysey et al., 2021) (Oxford/AstraZeneca, 53 million doses), BNT162b2 (Polack et al., 2020) (Pfizer/BioNTech, 40 million doses), NVX-CoV2373 (Novavax, 51 million doses), mRNA-1273 (Moderna, 25 million doses), and with CSL for local manufacture of the Oxford/AstraZeneca vaccine. The phased rollout of the vaccine programme, with initial priority to hotel quarantine staff and frontline healthcare workers, and the elderly (70 years and older), followed by younger age groups with selected underlying medical

conditions that increased their risk of more serious COVID-19, has been slower than anticipated, with around 3 million doses delivered by May 2021. The identification of thrombotic thrombocytopenia syndrome (TTS), including cerebral venous sinus thrombosis, linked to Oxford/AstraZeneca vaccination (generally occurring 4 to 20 days post-vaccine dose one) was a clear setback to rollout plans. Given relatively higher risk of events (overall around 1 in 100,000 to 150,000) in younger age groups and the lower COVID-19 morbidity and mortality risk, many countries have restricted the vaccine to older groups. In Australia, for those under 50 years, other vaccines are preferred.

COVID-19 vaccine real-world impacts

The rapid implementation of COVID-19 vaccines in settings with ongoing high infection rates has clearly demonstrated that impressive clinical trial efficacy has translated into high-level real-world effectiveness. In fact, it is relatively unique in that real-world effectiveness may have even exceeded expectations. This relates to the phase 3 clinical trials evaluating efficacy in relation to prevention of COVID-19 (symptomatic illness), but not being powered to fully evaluate efficacy against severe COVID-19 disease, hospitalization, and death. Furthermore, most trials were unable to evaluate efficacy in relation to prevention of all infections (including asymptomatic).

A key feature of the real-world data has been the similar effectiveness of COVID-19 vaccines that appeared to quite different efficacy in phase 3 trials. For example, in United Kingdom, both Pfizer/BioNTech and Oxford/AstraZeneca vaccines demonstrated effectiveness after the first dose (from 14 days) of around 90% against severe

disease and hospitalization, and 60–70% against all infections. The latter, coupled with a further United Kingdom study demonstrating that vaccine breakthrough cases have 40–50% reduced infectiousness (through evaluation of ongoing household-based infections), demonstrates the considerable impact COVID-19 should have on overall transmission. Further data from Israel, Qatar, and other settings has demonstrated similarly impressive real-world effectiveness of COVID-19 vaccines.

SARS-CoV-2 variants

Several new variants of SARS-CoV-2 have emerged, particularly in the setting of rapidly escalating epidemics. Those variants with either evidence of increased infectiousness, increased virulence (higher rates of severe disease), or reduced COVID-19 vaccine efficacy have been labelled “variants of concern”. These include the B.1.1.7, initially isolated in United Kingdom, which appears to have both increased infectiousness (30–50%) and increased virulence, but has relatively limited impact on COVID-19 vaccine effectiveness. In contrast, the B.1.351 variant, initially isolated in South Africa, may not have increased infectiousness or virulence, but has evidence for reduced COVID-19 vaccine efficacy. Other variants of concern include P.1 (Brazil origin), B.1.429/7 (United States origin), and B.1.617 (India origin) (Chakraborty et al., 2021).

Pathway to opening up for Australia

The considerable COVID-19 success that Australia has achieved through the pursuit of an elimination strategy has brought clear public health, societal, and economic benefits. The pathway out of the constraints of the pandemic will require careful con-

siderations of the risk of new community outbreaks against the potential benefits of opening up.

The Australian COVID-19 vaccination rollout should accelerate over the coming months, with the prospect that a large majority of adults could have received at least their initial dose by end-2021. Given the impact of both vaccines on risk of severe disease and hospitalization and the initial emphasis on older populations, such coverage should provide “disease immunity.” The impressive real-world data on vaccine effectiveness against all infections and infectiousness among breakthrough cases indicate that major herd immunity effects are also possible within this timeframe.

Several questions remain in relation to the opening-up. First, will people who have been fully vaccinated be allowed to travel internationally before full opening of borders, and what will the requirements be for quarantine on their return? Second, will the broader quarantine strategy be modified based on the vaccination status of returned travellers? Third, will children be required to be vaccinated prior to the opening-up? Presumably, this will depend on learnings from countries such as Israel and the United Kingdom with high adult population vaccine coverage before opening-up. This may be sufficient to prevent large outbreaks, including among children, particularly as they do appear to be both less susceptible to infection and less infectious.

Conclusion

COVID-19 holds a mirror to public health systems and finds any weaknesses. Based on this tenet, the Australian COVID-19 reflection is one of general positivity. Our public health systems have improved during the

epidemic, but have largely held up, particularly capacity for testing, contact tracing, and organisation of isolation. The community support for COVID-19 testing and restrictions has been superb, with surprisingly limited resistance to such measures. At times, bipartisanship has been lacking, and Federal-State collaboration sub-optimal, but political leadership has generally been sound and followed public health advice. The pathway to the COVID-19 “other side” will however require some risk as the country opens up, but assuming support for vaccination, major disease burden is unlikely.

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The weaving power of Indigenous storytelling — personal reflections on the impact of COVID-19 and the response of Indigenous communities

Distinguished Professor Larissa Behrendt

Associate Dean (Indigenous Research) at the University of Technology Sydney

Email: Larissa.Behrendt@uts.edu.au

Introduction

The academy has always been a complex place for Indigenous scholars. In first entering as students and graduates in the mid-1960s, the growing number of those choosing an academic pathway and career is slowly, yet fundamentally, altering the way research is undertaken and teaching and learning is done. From seeking to find spaces within the Western disciplines with a goal of “Indigenising” the curriculum and through modules on “Indigenous studies,” there is a growing move towards the inclusion of traditional knowledges, not just as a way to fit in with Western sciences, but as a knowledge system in their own right.

Research projects in the Indigenous space have moved from being “about Indigenous people” to working towards the concept of “Indigenous led-research.” Ethics processes and protocols have reflected these shifts. The privileging and valuing of the knowledge of Indigenous Elders and consideration of how Indigenous Cultural Intellectual Property (ICIP) will be treated are now central to framing research questions and methodologies.

These shifts are a reminder of how, now that the cohort of Indigenous academics has increased in the academy, fundamental shifts have taken place, even though they have been incremental over time. I start

with this reflection as a recognition of the way in which Indigenous people have been agents of change within the academy — and that they have entered it without leaving their concept of self-determination at the door.

I was in the town of Oak Valley, out on the lands of the Maralinga Tjarutja, working on a film project,¹ when news of a virus outbreak in Wuhan, China, started making international headlines. Oak Valley has the most remote health service in South Australia. The health service is community-controlled and its Aboriginal nurse is a central member of the local community. Oak Valley has its own Indigenous-run Council and is part of the Maralinga Tjaruta Lands Trust. The traditional owners had been moved off their lands when the atomic testing took place and, after a Royal Commission and continual community pressure on successive Federal governments to clean up contaminated land, it has been returned to full community control.²

As the understanding of the impact of COVID-19 grew, the health service swung into action with community meetings to discuss what was known about it and to pro-

¹ *Maralinga Tjarutja*, Blackfella Films, 2020.

² For a fulsome account of the fight by the Maralinga Tjaruta people to regain their lands, see Hiskey (2021).

vide information about hygiene and social distancing. As the threat loomed larger, talk began of closing the community off and the work started in ensuring that there was enough food and medical supplies.

It was noticeable at the time that, as the Federal and state governments struggled with the difficult task of balancing health imperatives with economic implications and the need to develop strategies for ensuring public health including closing borders and implementing other restrictions, these remote, self-governing communities could act swiftly to make the determinations about what was in their best interest. I often heard people express the view that they felt safe in the remoteness of their outstations and homelands. Communities like Oak Valley could be nimble. State and territory governments quickly supported their decisions but it was evidence of one of the many benefits of an empowered local governance structure.

Also highlighted in the quick response from Indigenous communities was the importance of the community-controlled sector. Community controlled health organisations from the start of the COVID-19 crisis did the heavy lifting in terms of community education and other precautions, including highlighting the need for flu and pneumococcal vaccinations to limit the risk of complications if people did get infected.³ Those targeted campaigns were culturally appropriate and targeted the most vulnerable in the Indigenous community who are often missed in large government roll-outs. They did this heavy lifting with limited resources.

However, as was the case with much of the way COVID-19 impacted the community, gaps in service delivery and other inequalities were quickly highlighted. The cost of fresh food has long been an issue in remote communities⁴ with negative implications on Indigenous health. It's cheaper to buy soft drink and chips in remote community stores compared to the high cost of fresh fruit and vegetables that have been largely attributable to high transportation costs. Even in communities such as Oak Valley where there is some capacity to supplement diets with healthy bush tucker, the cost of nutritious food remains an issue.

The other reminder of inequity was evident in the official listing of most "at risk" groups: people over 70, people over 60 with an underlying health issue and Aboriginal and Torres Strait Islander people over 50. This highlights the gap that still needs to be closed in terms of life expectancy and health outcomes such as higher rates of heart disease and diabetes in Indigenous communities.

One of the first, hardest hit areas when COVID-19 became a global pandemic was the performing arts and then the arts sector more generally. Performances were cancelled; venues and exhibitions closed.

Along with the rest of the sector, Indigenous performing arts companies were hard hit by this. Many of the smaller companies were focused on performances for tourists interested in local, traditional culture. As flights stopped and borders closed, Indigenous arts companies faced the further challenge of the loss of their key commercial markets. Community art centres often rely on tourists travelling through, so, with

³ See <https://www.naccho.org.au/covid-19-resources>

⁴ See Standing Committee on Indigenous Affairs (2020).

extended lockdowns and strict restrictions on movement in and out of remote communities, these small entrepreneurial industries suffered.

But it is misguided to assess the impact of COVID-19 on creative practice in Indigenous communities by simply looking at the impact on the arts and creative industries. Creative practice is part of a larger ecosystem in tight-knit communities and has profound impacts on cultural life.

Art practice such as painting, weaving and possum-cloak making is often still a very communal activity within the Indigenous communities. Restrictions on movement and gatherings have had an impact on these types of activities, limiting engagement in these important processes. Other important cultural practices, such as ceremonies, were impacted by closed borders and isolation restrictions.

When we think of the connection between culture and well-being for our mob, especially mental health, the lack of the community engagement brought on by COVID had a significant impact.⁵ Not only does it remind us that engagement with culture and cultural practice is a key factor in the wellbeing of Indigenous people, it should serve as a reminder that, universally, a connection with creativity and creative practice is enriching.

Despite the challenges that COVID and its restrictions have posed, there was optimism and opportunity — partly because the virus did not sweep through communities as was first rightly feared.

For many Indigenous people, the trials posed by COVID were just another set of challenges amongst many others, another

bump in the road. Resilience in Indigenous communities has developed over the centuries of colonisation — responding to dispossession from land, policies of removing children, strict controls over daily life, the introduction of diseases, the destruction of cultural sites. Lives have often been disrupted; Indigenous people have long been on the margins. We are used to being at the bottom of the socio-economic ladder. While this global crisis is like no other in our lifetime, it was just one more disaster to threaten Indigenous communities. As one Elder said to me, “We’ve survived small pox, we can survive this.” In that dark humour lives a resilience that speaks to a continuing resistance to colonisation and all its myriad impacts.

While the impact on communal practice and ceremony was deeply felt, personal engagement with cultural practice remained strong. Many people re-engaged more intimately in connection to culture. I began my brother’s possum coat as a way to keep strong in the culture in a more personal way, though the usual way to make the coat is communal. By preparing the skins and starting the burning of the patterns, it was ready to sew as a family, a space to share stories about my brother, to share with his children, when we were able to come back together as a broader family network.

Artists themselves have been entrepreneurial. Indigenous people have a good take-up of technology.⁶ It is access, not adaptability, that is an issue. Artists’ collectives are selling on-line; art markets and festivals are going virtual.⁷ One instructive example was Dance Rites, an annual

⁵ Human Rights and Equal Opportunity Commission (1997).

⁶ Rice et al. (2016).

⁷ See <https://aiatsis.gov.au/iam>

program put together by Rhoda Roberts at the Sydney Opera House.⁸ Before COVID, it would have been unthinkable to suggest that such an important cultural event, one that brings together performers from all over the country, could be done virtually, missing the important element of people meeting and connecting. But the event was undertaken by recording people locally around the country. Elders who would not have been able to travel to Sydney because of age and/or illness could participate. And the format meant that important dances were recorded for the community. While not the same, there were clear benefits in a virtual event. And while it is also not the same for an audience to see dance performed virtually as it is to see it live, there is a potential for a much larger number to access it. And it is important to performers that they get to perform.

The pandemic has highlighted many weaknesses in our economic, democratic and social systems that were just cracks before that were easily papered over. Vulnerability in the employment market and fragility in the housing market are two areas where those with less security are feeling the pinch, while those with economic certainty are more easily weathering the storm. The difference between the “haves” and “have nots” is coming into starker relief.

Perhaps that is one reason that explains why there has been a bigger response to the Black Lives Matter movement by the broader Australian community during the pandemic than at any time leading up to it. I’ve been marching against Deaths in Cus-

tody since I was a child and a turnout of fifty or more would be greeted as a sign that the tide was turning.

To have seen the tens of thousands who turned out across the country to give support to the Black Lives Matter movement showed a fundamental shift. After each death in custody in Australia, another family, another Indigenous community has been mobilised. All of those deaths were unjust. But something shifted when it was impossible not to draw comparisons to the death of George Floyd in Minneapolis on 25 May 2020, and David Dungay Jr in Long Bay Correctional Centre, Sydney on 29 December 2015, when both men’s last words were, “I can’t breathe”.⁹

I’m not signalling this as necessarily leading to the changes we’ve long advocated for, but there is a different discussion now in the mainstream that acknowledges that there is such a thing as systemic racism that was reflected in the language used at the Black Lives Matter rallies. Signs read: “End White Supremacy” and “White Privilege is the Problem.” These are slogans I never saw in my youth. Discussions about systemic racism and complicity in colonial systems that have long existed but have now moved from the academy into the streets.

COVID-19 almost eclipsed the preceding summer of apocalyptic bushfires. Through the lethal and intense burning of bush and homes that shattered communities and decimated ecosystems, there was furtive questioning about the extent to which we can manage the climate crisis. This has led to an increased inter-

⁸ See <https://www.sydneyoperahouse.com/festivals/dance-rites.html>

⁹ <https://www.theguardian.com/australia-news/2020/jun/01/family-of-david-dungay-who-died-in-custody-express-solidarity-with-family-of-george-floyd>

est in Indigenous knowledges, particularly around fire-burning technology¹⁰ and sustainability practices. The profound cultural impact of Bruce Pascoe's *Dark Emu*¹¹ has also seen more Australians think deeply about the way they live on this country and what the people who survived on it for over sixty-five thousand years may have to teach us about it.

During the period of the COVID lockdown I updated my book, *Indigenous Australia for Dummies*.¹² It had been ten years since its publication and there was a lot of catching up to do. While socio-economic statistics needed updating, they had not shifted too much — education and some health outcomes were improving; rates of over-representation in the criminal justice system and out-of-home cares systems were increasing. The two areas that required the most work were the areas of Indigenous knowledges and in performing arts and literature. There is a renaissance of Indigenous filmmaking, performance and writing: proof that the storytelling traditions are alive and well.

There is an increasing understanding that Indigenous stories need to be led by Indigenous people. And there is an increasing awareness that the strongest storytelling comes from Indigenous perspective. More and more there is broader acceptance of Indigenous stories as Australian stories — as *the* Australian stories.

Because of the relative containment of COVID in Australia, we were amongst the first in the world to be ready to perform and create again. Major film productions moved

here; people returned to the stage ahead of the rest of the world. This had additional advantages for local performers. The 2021 Sydney Festival was the first in the world to return to in-person events. Headed by Artistic Director, Wesley Enoch, the Festival combined risk management and strategic and deliberate investment in our local content with a program of all-Australian talent. While fluid border restrictions caused their own logistical nightmare, the Festival was a success — the first opportunity for many performers to take to the stage in front of a live audience. In perhaps a sign of things to come, live events were often available with virtual options for the audience. You can watch in the venue; or at home. Again, this opened up the Festival to those who could not travel to Sydney.

This adaptability gives me optimism about what regeneration post-COVID-19 looks like, with a focus on the importance of the role of creativity and performing arts as a way of building communities and bringing us back together. As we rebuild, story is a way to heal and strengthen. I think of it like weaving, and as our stories intersect and we find our connections and how we are tied to each other, the fabric becomes stronger — there is a cohesiveness that builds.

With the vaccines now rolling out, there is quiet optimism that Indigenous communities across Australia have avoided the fates of other First Nations around the globe, particularly the Navajo Nation in the United States.¹³ It is a credit to our community-controlled organisations and their ability to respond to cultural needs and to the nimble regional and local self-governance systems.

¹⁰ Steffensen (2020).

¹¹ Pascoe (2014).

¹² Behrendt (2021).

¹³ Cheetham (2020).

They are providing further proof that the principle of self-determination is not just a lofty ideal and a central human right — it is an effective and efficient framework for policy and service provision.

Communities like Oak Valley, who so quickly and ably turned their attention to the safety and well-being of the people who lived there, need to be recognised for their role in achieving the results. The Closing the Gap agenda has been rebooted, including justice and child protection strategies. Its progress and the implementation of strategy is now overseen by a Partnership Agreement that sees Indigenous peak bodies take a seat at the table beside government. Hopefully this will avoid the practice in the past of governments who funded non-Indigenous NGOs to do the rebuilding or the work being funded through stimulus at the expense of the Indigenous community-controlled organisations who have done the heavy lifting through the crisis.

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For what it's worth

Bethwyn Serow

Arts and Policy Strategist

Email: bserow@gmail.com

Abstract

The COVID-19 pandemic has had great economic impact on and yielded much information about the value of the performing arts. Most performing arts enterprises are not-for-profit, highly geared in the market, and require upfront investment ahead of uncertain returns. COVID-19 borders created special challenges for interstate and international co-productions and elite performers. Performing artists were hit especially hard during the pandemic necessitating rapid shifts in operational and funding strategies. A deep sense of isolation and loss of arts events drove a highly engaged uptake by audiences of digital performances, livestreamed and recorded, and public recognition of the central place that culture and creativity play in the daily lives of most Australians. The pandemic has driven adaptation and innovation in arts digital production and engagement with the expectation that this platform will persist post-COVID, potentially deepening and expanding access. Collectively strategising to strengthen the interconnections between arts and industries such as tourism and hospitality and retail, health, education and general wellbeing and cohesiveness of our community may well uncover opportunities for us to build back better.

Introduction

I pay my respects to the traditional owners of the land on which we gather today, the Gadigal people, the Eora nation. And to thank Larissa and her colleagues in the arts. I came through an education system that gave me a minimal grounding in First Nation's culture and history. I acknowledge the incredible generosity extended to me by many First Nations people across the 20-plus years of working in arts and screen. Conversations that have been both enriching and humbling. It has also reinforced the vital and strengthening impact that comes from engaging and respecting the human expression fostered within the arts and culture.

Working in the arts and screen sector and in their advocacy for many years I have experienced some fantastic highs. When we see ambitious creative confidence, politi-

cal recognition and public discourse seeding real engagement, it's thrilling, there's energy, and then things dissipate. While the arts are moving hearts and minds on the stage, when the curtain falls, we are often lamenting together of our maligned state, and the need to constantly reiterate our value. Continually we call for a place at the policy table only to be repeatedly thwarted with naysayers marginalising the arts as something you do once more pressing matters have been addressed. Frankly, it's exhausting. It's blocking our progress, and it's limiting our growth as a modern, dynamic society. We have much Australian artistic talent and creativity under realised, there is much more we could do.

Australia has benefited from the ubiquitous nature of the arts and the positive impacts it makes. There's a whole shopping list of positive value, from wellbeing

and health to education, social cohesion, as Larissa's been talking about, placemaking, stimulating tourism and retail, and stories, and international our brand and cultural diplomacy. I sometimes I think if our list were shorter, we'd be taken more seriously, that people believe that we keep trying to find a winning argument for the value of the arts rather than the collective list being true and impactful. Everything we do, in every faculty, in every part of our how we live, is infused and shaped by our humanness. What humanity is, its form, its influences, its power and fragility are explored, expressed and challenged within the Arts.

Federally, there are individual ministers and members of the backbench who acknowledge the value of the arts. However, there's very little cross-portfolio collaboration. Without a strategic roadmap, confident leadership and proactive investment to explore creativity and innovative ways to advance our 21ST century social and economic challenges in partnership with the arts, our shared wellbeing and prosperity is under-realised.

And then came COVID.

COVID-19 impact

The performing arts were, as Larissa said, the first sector to experience the full force of social distancing and shutdown measures, and it will be the last to recover. All earned income dried up overnight, and much of the cash on hand represents sales for future shows, which were soon cancelled, and the refunding of tickets became a financial and logistical issue. In many cases those pre-sales had cash flowed rehearsals, sets and costume construction and the associated pre-production behind the scenes work. Performing arts organisations use subscriptions

and reserves to invest upfront. They carry significant financial risk. Some of our largest organisations have less than 10 per cent subsidy and returns are calculated over the annual season. One show cross-subsidises another. COVID cannibalised any notion of a balanced season and for many, any season at all. And all the upfront investments were lost because income and expenditure are very lumpy.

The 2018 Live Performance Australia's ticketing survey indicates the scale of mainstage and refunds alone. It reported the performing arts and live entertainment generated 26 million performance tickets were, more than the AFL, rugby league cricket, soccer, basketball and baseball tickets per year.

The box office of the eight major performing arts theatre companies in Australia alone generates more in earnings each year than the Australian feature film industry.¹ These performing arts companies also cancelled non-ticketed events in education, community development, development of artworks and experimentation.

The ABS verified the size and speed of COVID impact. In the week of the 30th of March, it estimated that 90 per cent of businesses across the Australian economy were still operating. In the arts, but particularly the performing arts, it was down to 47 per cent, making it one of the industry's worst affected. The Grattan Institute estimated nationally 14 to 26 per cent of jobs were lost in the workforce, whereas in the arts sector it was 50 per cent.

¹ The combined box-office of the eight major theatre companies in 2019 was \$54.9m directly sourced from the Australia Council for the Arts. The Australian feature film box office was \$22.6m.

Performing arts sector response

So what did the performing arts companies do? Where did they start?

Key priorities included retaining their artistic virtuosity and knowledge embodied within their ensemble of performers and creative teams and keeping connections with the audience. Ensembles are critical to capacity building in the future, and they hold the art within their bodies. A dancer at The Australian Ballet or Sydney Dance Company hold works within themselves developed over 5, 10, or 15 years. The work that they do together is like a well-oiled team in a football league. You pick and choose your ensemble to complement and explore a certain style of expression, holding onto the ensemble is very important.

Reserves, flexibility from state and federal governments on current grant deliverables and Jobkeeper have supported some arts organisations. But as Larissa alluded to, for the companies that don't have ensembles, mostly in theatre and dance, none of their performers, all of whom work on short term contracts were eligible for Jobkeeper. Here we had a theatre company without permission to open their venues and no support to retain artists who might then prepare for future openings or help engage with their audiences online. It's a bit like coffee not being available at a café, or hospitals without doctors. Where can you go with the arts, without artists?

Arts audience response

The deeper interconnection between the arts and the community, and we've talked about this today, has been significant. The response of the Australian community in COVID has really shaped the nation. In the arts it reinforced that our tickets are

not merely ticket sales. Many patrons willingly converted their tickets to either next year's season, showing faith that we would return. Many also turned their tickets into a donation, gratefully received both from a financial point of view and for the heart that it gave artists, performers, and organisations.

Signed up sponsors also stayed on board, they worked with companies to repurpose their sponsorship where they could. This supported some arts organisations going directly online while others suspended their initiatives. Philanthropists provided emergency financial relief to artists slipping through the cracks; a recent Queensland Ballet video captures the sentiment.

People across the sector worked hard. While on paper they are on reduced hours and reduced pay, they are often working long hours to respond to COVID and maintain contact with the public. They also facilitated shows to raise money for the benevolent funds across the sector, including Equity and special independent artists funds. But, of course, these are all stop-gap measures.

Government response

A lot of my work in COVID was lobbying and advocacy to the federal government. The government announced a \$250 million support arts package to COVID in June, which was gratefully received. It wasn't considered enough, but it was fantastic to see a sense of partnership returning. However, that was four months into COVID. We are now seven, moving to eight months in, and we have not seen one dollar come from that process. Many in the sector argue on all sides, from all traditions that this is simply not good enough and that we are losing precious cultural commodities.

Arts employment drift

According to the ABS, accommodation and food services and arts and recreation centres are experiencing higher COVID unemployment than any other sector, which I think you might have seen in the news. But what is of keen interest, so much so that the ABS has commented on the finding, is that in the arts and cultural sector, the slight improvement in employment is actually people from the arts moving out of the sector to find work. So we are now rapidly losing our talent, driven by a combination of being the last to return and ineligibility for Jobkeeper has meant we couldn't keep people attached to our organisations.

Audience digital uptake

While many wonder why the government has been moving so slowly, Australians themselves have actually been increasingly engaging and somewhat embracing the arts. The Australia Council for the Arts' Creating Our Future report, released in August revealed Australia's recognition of the power and the value of arts has grown since 2016. A new statistic also notes that the arts help build necessary skills for our workforce future. Another report also released during COVID by the independent think-tank, a New Approach focused on middle Australians. They expressed similarly high levels of value recognition, agreeing that the arts and culture are a means of connecting communities and embracing our national identity, our Australian way of life, ironically, they also suggest that Australia would be an authoritarian or war-torn nation without it. The report also reinforced Australians place significant importance on the value of the arts in developing creativity in children and helping address mental health and improve

wellbeing. So while our financial stocks are down, in this time of crisis, our social stocks have been growing.

In lockdown, just over a third of Australians engaged in the arts online and another third surveyed early in the piece said they weren't engaged with the arts online, but they'd like to know how. And of those who did, 19 per cent said they were doing more, engaging with the outside world than they had previously. For children, it was 48 per cent more. Interestingly 25 per cent said they felt that they were more creative than before COVID. So we've given the nation a productivity boost.

ABC Classic Radio has also reported a significant increase in its listeners to classical music and other programs. And in the major performing arts companies, the arts education teams who pivoted online have reached schools and children that they've never had the resources to travel to before.

Performing arts digital output

Throughout COVID, the sector developed new digital skills and rich and varied content, but it was all on the fly. As I come from a screen background, the first thing I thought when I moved across into the performing arts is great; we can build greater collaboration between screen and the performing arts. But there have been barriers. In fact the time and the investment have not been there to make it possible on any scale. So in effect, the crisis found us the time, whether we wanted it or not. Goodwill, ingenuity and sector resilience has led to some amazing digital pivots. For example, Malthouse created digital packages and sent it out to the various casts they had planned to work with through the year with instructions of how to make their own videos and

podcasts at home. We had digital choirs, play readings, interviews, and for the artists that weren't on Jobkeeper, the companies that had some reserves also tried to create little projects where they could call artists into work at a distance. From three musicians standing apart in a studio to record some performances to performances in empty concert halls. The ABC stepped up, and I don't think enough acknowledgement has been given to the ABC in relation to their support for the Arts during COVID. They announced very early that they would make a deliberate decision to program more Australian music on the radio and to provide any facilities they could to co-host artists, virtual festivals, and events.

The Griffin Lock-In, a partnership with Google, was another exciting offering. Five writers had a week to write a play, that was then performed live online. Audiences could interact with chat prompts that would change the shape of the play. While we have seen many organisations apply a broadcasting model to generate content online, they were trying to experiment, exploring other ways in which you could capture the live performance experience. While we celebrate any extra reach that online might offer, we know live experience of performance is not captured in its entirety through a video viewing. Bringing people together has a very different dynamic.

Hopefully, this investment in digital will continue because there is limited co-creation crossover between the screen sector, digital innovation, and the performing arts, even though we often rely on the same actors, and writers and so forth. It's also been shown that feature films based on plays generally do better at the box office. So we've got a lot of relationships, but little partnering and experimentation — the weave is not quite

there yet. That's why the work that is happening in this digital space is quite exciting.

Streaming performances online has been enabled through a special COVID agreement between Live Performance Australia, which is the main peak body for producers, production companies and the union Equity. Rights and clearance fees have been reduced during COVID, facilitating greater public access. Of course, we know that actors and the creation of content and livelihoods of many arts workers do not survive on goodwill alone and we do need to develop better ways to monetise some of this activity in the longer term.

The Melbourne Digital Concert Hall is an innovation to watch. Two young artists, again on the fly, created a new digital concert proposition. The model was simple. Twenty dollars for a ticket that twenty dollars all up went to the artists — the four dollars booking fee paid for everything else, the technicians and the software to program. In the first two months, they raised \$100,000, and they thought that was terrific. Last week they'd raised \$750,000. They've provided income to 350 artists. They've had 175 concerts and 40 per cent of their viewers don't usually attend in person. This is due to various situations, including having young children, health issues; living too far out and work demands. We're hoping the initiative will retain engagement with these other types of audiences.

Sydney Dance Company were one of the first to go online with this offering of dance classes at home. They have an ensemble of artists that they also needed to maintain. Artists often gain energy and purpose and an understanding of themselves, through performing. Supporting elite artists' physical fitness is not the only challenge, often harder to address is maintaining creativity in such an austere situation. Sydney Dance

Company was about to open a new work just three days after the COVID lockdown. They ended up turning the ensemble into dance teachers. It has been a learning curve, but they have generated revenue, sustaining the company in a way they didn't expect. They also had some international artists who aren't eligible for any government welfare schemes, and this income has helped to support those colleagues.

Incredible problem-solving stories are not just in the arts. Creativity is not the sole domain of artists or the cultural industries, but creativity is critical to the arts, and the arts nurtures our creativity.

Performing arts and creative industries

Ogilvy Australia CEO David Fox wrote in his recent federal COVID arts submission, 'Finding new solutions to a long-standing challenge is only possible because our people have been influenced to think outside the box. They have been inspired to push the envelope, and it comes back to having proximity and exposure to the transformational thinking that the arts invite.

The data released last month on the creative industries measure the share of GDP as 6.3 per cent and the value of \$115.1 million. That's a 10-year growth of 34 per cent and \$88.1 billion in gross value add. These are not bad figures, and the arts and recreation services themselves reported 6.8 per cent growth, a little bit higher in turnover and eight per cent growth in employment. That's 216,000 jobs directly. And we know there are other creative jobs in other industries. Arts and recreation were delivery some of the highest job growth results before COVID after health care and social services. It shows that the arts are a very fertile place and where we can gain social and economic benefits.

The creative arts generated more jobs than mining, finance, utilities and information media and technology sectors. In 2018 the UK creative industries grew five times faster than the rest of their economy. The Australian performing arts is relatively small within our creative sector. They've generated \$4.3 billion, representing a 37 per cent growth over ten years, slightly ahead of creative industries. But they carry within them that pure experimentation and the sort of boundless possibilities of creativity that act a little like a furnace.

Arts tourism and night-time economy

The economic value of the arts is more than its direct inputs outputs. The arts generate secondary retail and hospitality activity, and almost all their expenditures occur within the country. They are also empowering a lot of interconnections that we can foster in our recovery.

In the five years to 2017, the international arts tourism made up 43 per cent of all international tourism. It was growing faster than the rest of tourism and arts tourists spend more. Now we know they're not coming for a little while yet, but domestic growth in arts tourism, both day trips and overnight has also been encouraging. So since 2013, day trips have grown by 14 per cent overnight by 20 per cent; again, the arts tourist spends more money.

COVID has shattered the night-time economy. Our silent, empty cities are raising concerns, and the arts have a role to play here. Historically, the night-time economy has grown faster than the rest of the economy, and the arts are crucial to bringing people into the city. Importantly, arts engagement is not merely about the economic hook; it's really about attracting

people in an impactful way and invites connection beyond the market transaction.

Adaptation of live performance

This weekend just gone, there was an amazing festival in Western Australia called Good Day Sunshine Busselton Music Festival. They basically got a car rotator in a showroom and put their band on there and then they segmented the big oval into four parts, and you couldn't cross over into different quadrants. They have managed to create a way to host a crowd of up to 5000. I know at least two quadrants were sold out. And they've had the first mass gathering in Australia, and it's the first one we know of internationally. And it went well.

Melbourne Fringe is delivering performance art by letterboxes, by the telephone. You can ring up an artist and give them any problem you have in your private or professional life, and the artists will provide you with an artistic solution. Circus and dance with their reliance on body and touch, of course, have had to adapt. So they're creating with distance, they're developing work that is not relying on touch.

On the other end of the spectrum questions about whether opera will be able to come back at the size and scale that we've had in the past suggest it will take a very long time. Symphonies can't program Mahler or Rachmaninoff because it's just too big. We can't fit those artists on stage in a COVID-safe way. So we're going to see a change in what we program. We can't fly in international artists, something symphonies in particular, and sometimes the ballets and operas, rely on. So again, it will be Australian artists, but it will also be arts in smaller spaces. Sydney Symphony is bringing some of the Australian artists who are not able to

work in Europe home to Sydney and programming, so there's a sliver of a silver lining.

After all this, the sector continues to pivot, but it is fragile. People are depleted, and it is not only the financial gaps in the ecology that need attention.

Arts reform remit and outlook

We need to support building the central role of First Nations arts and culture, and the sustainability of their practice. We also need to provide professional opportunities for minority cultures in Australia to build career paths in the arts, and there were already art form gaps before COVID that require attention. The Jobkeeper extension to March helps some, but it will end in March, and we won't be back to full capacity at the box office, and philanthropy is expected to drop by 30 per cent in 2021.

A survey on people's confidence in coming to the theatre has said nationally 29 per cent of people are ready to go to the theatre when they're told it is safe to do so. Twenty-nine is not a very big number, and so far, no one has caught COVID in a theatre. In comparison, audiences are quite happy to eat at their local restaurant — 85 per cent, go to the gym, 53 per cent — or go on a plane interstate at 48 per cent. We see many different scenarios play out in the various states — that also impacts the sector because border closures have stopped interstate co-productions and the economies of scale that these partnerships enable. We know that we're only one incident away from closure. So even as we open, we know our sector remains at the highest risk of being closed, and we rely on everyone to get it right.

Finally, in 2019, the UN General Assembly declared 2021 as the International Year of the Creative Economy for Sustainable Develop-

ment. Our closest neighbour, Indonesia, took this idea to the UN meeting, and Australia² was a one of its numerous supporters.

As a country, there is much to do. We have seen communities unify and we've talked about this today. We have seen systematic failures, inadequate protections and some 'othering' of our vulnerable people and disconnection of minority cultures to our broader cultural conversations. Addressing our mental health, education disengagement, people's confidence, reinvigorating our cities, increasing sustainable industries as we pursue economic growth and job creation are key challenges heightened by COVID. And we need to ask, is the old playbook where the arts are something you do at the end of the day fit for purpose? Or can we do better?

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² Other countries in the global grouping: China, India, Indonesia, Mongolia, Philippines, and Thailand.



Is the COVID moment a time for reform? Discussion

Martin Parkinson¹, Anne Tiernan², Julianne Schultz³

¹Chancellor, Macquarie University
Email: martin.l.parkinson@gmail.com

²Dean (Engagement), Griffith Business School, Griffith University
Email: a.tiernan@griffith.edu.au

³Media and Culture, Griffith University
Email: Julianne.Schultz@griffith.edu.au

Abstract

Prof Knight: Our final session today is on reshaping Australia's institutions. My task today is to invite my colleague Julianne Schultz to moderate this session. Julianne is the Professor of Media and Culture at Griffith University and Chair of *The Conversation*.

Prof Schultz: Thank you, Eric. I would like to introduce Dr Martin Parkinson, who is one of the two panellists in this session. This session is going to be slightly different from the rest of the day, more a discussion between myself, Martin Parkinson and Professor Anne Tiernan, who is behind the border in Queensland. And while Anne could have travelled to Sydney, she couldn't get back to Brisbane without going into quarantine for two weeks. She's a very loyal Queensland, but that was a price too high.

Like the other presenters I would like to acknowledge the traditional owners, the Gadigal people of the Eora nation.

This conversation is about how to use the COVID moment as a time for reform, how to use this crisis to think quite fundamentally about the big issues of governance and public organisation and so on. Before we start I would like to note that I found the Governor's welcome this morning, speaking in language, to be profoundly moving. That she should do so in this place, at the epicentre of colonisation in Australia is par-

ticularly noteworthy. That the state's governor would speak, acknowledging traditional owners using their language, sends a very important signal that we are ready for quite big changes in this country, even though we remain rather diffident about it.

So in that context we are going to be discussing how to use a crisis. As Professor Genevieve Bell said earlier, this is a liminal moment. The question is how we might emerge, what opportunities are there to re-establish new ways of doing things or ways of really building on the strengths of the past, to create something which maybe fosters a new normal going forward.

The pandemic has really reminded us of the importance of good governance and of capable and appropriately responsive public sector institutions in fulfilling the state's duty of care to its citizens, economy and society. The discussion that we are going to have is going to develop that. I must say that I thought the presentation and discussion from the New South Wales health people earlier today really was a great indication

of the capacity of a well-resourced, well-thought-out and capable public sector to step up to the mark in a really profound way. And I found that description that Teresa Anderson gave, about how the organisation of the New South Wales public health sector had actually operated, was a really powerful model of what might be one of the best things that we might take forward.

In this discussion, we are going to talk about that. We'll talk about the strengths and weaknesses that have been revealed by the COVID X-ray, the lessons and new opportunities for reform, and reflect on our capacity to create the sort of society and the future that we want to have in the future. The challenge goes beyond recognising the problems and the opportunities. The bigger task is really how to mobilise that collective ability and willingness to act to address them. The failure to do so will have ramifications for generations, but the right response has the potential to set the country up in a really strong way to look further for the future.

This is not a crisis to waste, and the cost of failure could linger for generations. Success could be transformative and set the country up to really thrive. In starting that discussion, let me introduce our guests. Martin is most recently the head of the Prime Minister's Department and is now Chancellor at Macquarie University, amongst a number of other important roles. And Anne Tiernan, whom you can see on the screen — hello, Anne — is the Dean of Engagement in the Griffith Business School at Griffith University. She's a member of the Board of the Museum of Australian Democracy and occupies a number of other important public policy positions.

I'm going to start by just reading a little quote that comes from an Anne Applebaum's terrific new book *Twilight of Democracy*. She wrote, "Throughout history, pandemics have led to an expansion of the power of the state. At times when people fear death, they go along with measures that they believe, rightly or wrongly, will save them, even if it means a loss of freedom."

In Australia, there was a consensus that people needed to stay at home, that quarantines needed to be enforced, that police needed to play an exceptional role. But in some other countries, fear of disease became another inspiration for a whole new generation of authoritarian nationalists. My opening question to Martin and to Anne is: what has surprised, excited and disappointed you about the Australian response? Martin, we'll start with you.

Dr Parkinson: Thanks, Julianne. And as someone who lives on Ngunnawal country, allow me to associate myself with an acknowledgement of country that was given by our colleagues earlier, and extend that to people who, from wherever they are around the country, are on Aboriginal land.

I think it's worth separating two issues. I'll focus predominantly on the economic, rather than the social issues, that COVID has just opened up. It's worth separating the economic crisis from the medical crisis that initiated it. If I think about crises, it's useful to think of three lags. The first is the recognition lag. How long does it take policymakers to realise something is occurring and they need to change course? Then there's a reaction lag or gestation lag. How long does it take them to work out what it is that they should do? And then third, there is a response lag. How long does it take for

their actions to begin to have the impact that they're attempting to create?

So, if I think about the medical dimension of this crisis, I think we were very, very quick to recognise the emergence of, what we believed to be, the Wuhan-based virus. And remember, the Australian government closed the border to people from China on the 1st of February. And I think it was about the 3rd or 4th of February before the WHO declared that it was a pandemic. So government was very quick to recognise. They were very quick to react, and by this, I mean both the Commonwealth and the states together as the Federation, they were very quick to react and to put in place policies to settle on an approach of trying to bend the curve, not eliminate the virus.

Putting Victoria aside for a minute, I think the speed with which the policies they put in place actually had impact was really quite remarkable in the circumstances. I say put Victoria apart because I think it was inevitable we were going to have "a Victoria." It was going to happen somewhere, because, by the very nature of the virus, there would be some form of secondary breakout. Now, could Victoria have done better or worse? Clearly, it could have done a lot better. We've lost a lot of Australians because of those circumstances.

But if you think about the medical side, I've been really excited and surprised by how quickly we moved and also by the reliance on expertise and the trust that the community has put in to the chief medical officers when they've been standing up there talking about what needs to be done. And I put that down to a couple of things. Like Shane Fitzsimmons and the other fire chiefs back in December and January, they treated the Australian public like adults. They were

open with them. They were transparent with them. They gave them data. And what happens? The public responds by putting trust and faith in those people. And I think that is a lesson our political class needs to take away from this. Treat the public as adults, share with them what the issues are in an open and honest way, rather than trying to spin it for short term political advantage. And ultimately, you will get — you'll find yourself in a better position.

If I think about the economic crisis, those same three lags, we were very quick to recognise the economic implications. We were seeing the public sector designing Jobkeeper and Jobseeker within days of recognising what was going on. So the recognition of the economic consequences, which were going to be severe, was very quick. The reaction was very quick and the response to that dimension of it was very quick.

Now there is a separate set of issues which came about with the budget, and I'll come back to those because they're in the disappointment bucket. I was really pleased to see the embrace of fiscal activism rather than the fixation on the budget surplus. The budget surplus fixation was arguably sensible policy in a different set of circumstances. Circumstances changed. The political class changed. You know, it's that classic thing: why did you change your mind? Well, the facts changed, sir. They did the right thing.

I suppose the other thing is, I think the thing that's pleased me is the recognition with Jobseeker, that we can't really go back to the sorts of unemployment benefit levels that we'd had prior to the crisis.

And quickly, on the two disappointments. **Prof Schultz:** Save the disappointments. We'll bring Anne in on the pleased and the surprised and delighted, and we'll wrap

up disappointments together. Anne, what excited and surprised you about the Australian response?

Prof Tiernan: Thanks, Julianne, and good afternoon everybody. I'm from Jagera and Turrbal country on the edge of the Brisbane River here at Southbank. Sorry not to be able to be there. What surprised me? I work with the public sector every day in different jurisdictions around Australasia. So I wasn't surprised by the latent capability for innovation, a lot of which Teresa described earlier today. But I was delighted that the rest of the country got to see this and to appreciate that capability and expertise that exists in the public sector.

Martin talked about the speed of the response. I'm really pleased that the X-ray has revealed the kind of hidden wiring that really drives our public policy system, our Federation, and the Australian Health Protection Principal Committee, for example. None of us knew what the acronym AHPPC stood for, but we do now. It is an incredibly powerful mechanism for insight, early warning, access to data, information and evidence and projections around the epidemiology of the pandemic. That has pleased and surprised me, the level of innovation. Martin referenced the community as co-producers of outcomes in this, and I think that has been extraordinary. I think it's something that governments often don't think about — the public as co-producers — and they've really demonstrated the capacity to do that.

The other thing that surprised me, while it lasted, was the big effort that political combatants made to try and put their differences on a leash. And you could see what a struggle it was, Julianne. It lasted for a while through national cabinet before everybody

reverted to their same habits again. I'd be keen to come back to a conversation about habits and cultures in terms of what we need to get through the crisis. But I've seen some amazing things in terms of cross-sectoral partnerships. Teresa alluded to some of that as well in terms of the public, private and community sectors working together. There's been some extraordinary examples of that and real social innovation and individual communities stepping up and stepping in to do things and work together. These are pretty strong foundations from which to take some lessons from the pandemic.

Prof Schultz: Martin, let's just flip it now to a couple of the disappointments.

Dr Parkinson: Right. Disappointments. I think we have to set two tests for the fiscal stimulus, and we're not in a position to judge yet because arguably we can run through until the May budget next year to see what comes next. But the two tests were the economic response — is it likely to generate jobs and growth in the short term? Arguably, yes. I think it deserves an absolute pass mark there. You can argue about the composition at the margins, but I think they've done a pretty good job. Second question, much more open-ended. Does the fiscal stimulus — and think about the magnitude of this, we're going to end up with a debt to GDP ratio heading towards 50 per cent and over a trillion dollars' worth of debt — position us better for the future? If we're going to spend all that money, does it position us better, either because we're more innovative, we're more productive or we've set ourselves up to deal with a big problem, e.g. climate change? To date we haven't seen that money being directed to those sorts of issues.

Second issue is that the composition of the stimulus: to date that has been what I

would see as akin to fighting the recession of the early '90s. It's predominantly gone to areas where the professions or the occupations are predominantly male-dominated. And yet the initial hit — and I say initial because this will change over time — the initial hit has been on areas dominated by women and young workers. And so there will be very long-term consequences on the gender wage gap, the difference between male and female superannuation balances. If you're starting out in the job market today, you're likely to have lower lifetime earnings than if you'd started out even just a couple of years ago.

Prof Schultz: Anne, before I go to you, I just want to follow through this little bit with Martin. You've been in those very senior jobs as head of departments in Treasury and Climate Change, and Prime Minister and Cabinet. Throughout most of your career, money has been tight, it's been about balanced budgets. No new policy could be implemented if it needed "new money" essentially. All of a sudden there is lots of money, money's not the problem. And I'm not asking you to criticise those who have succeeded you in the role, but I'm just wondering how, in that sort of environment, in the Treasury, Prime Minister and Cabinet office environment, could you have argued for different outcomes along the lines that you're suggesting? You're saying that, in a way, the budget response has addressed a short-term problem rather than set us up for a longer-term outcome.

Dr Parkinson: Look, I don't want to be critical because you're in the midst of a crisis and so often, in the midst of a crisis, your horizon is really close to your face. And so going for the traditional instruments, it's not an unusual response. But this was the

first budget ever to be put together without a budget constraint. Once you decided it didn't matter whether we were going to have a \$150 billion deficit or a \$200 billion deficit or a \$250 billion deficit — and it didn't because once you are in those ball-parks, we're talking the economic differential — the long term is neither here nor there. I would have liked to have seen a real clear focus on how does this set Australia up for the future? And that could have been fostering innovation, accelerating digitization and automation or, encouraging — and there's been a little bit of this, I'm not saying there's none — but encouraging faster response in the climate change space or modern manufacturing, or fill in whatever it is that you're most interested in. And I'd say, if I could, my third disappointment has been the revealed attitude towards the higher education sector. It is not just the creative arts.

Prof Schultz: Education is a crucial one. So — and, Anne, I'm going to come to you in a second — I just want to follow this through for a few minutes. You say that when you're in a crisis, you deal with what you've got in front of you, and that is an obvious pressure and constraint. But this is something which is completely different, so the ballpark changes. I'm just interested in the process by which the advice that becomes available and where you draw it from in those roles. In a way the limitation is the available advice, and I say this in the context of the Royal Society and the Four Academies where there are very different disciplinary bases. There are people who come at these big problems from many different disciplines. It seems to me that the advice that filters through to Canberra now, and has done for a long time, comes from very much a narrower economic base than

you would get if, for instance, you drew on the full range of sort of intellectual resources from the humanities, the sciences, the technology sciences and social sciences. I wonder whether that is part of the problem in terms of the thinking being short term, that the frame a bit too narrow.

Dr Parkinson: No, I actually disagree with the premise. You're getting advice from the social welfare departments, from the Health department, from Human Services, from Social Services. You're getting advice from the Industry department. We've had a National Innovation Strategy but it hasn't gone very far. We have had a Digital Economy Strategy, but it hasn't gone very far. The reason these things haven't gone very far is because the political process hasn't wanted to pick them up and run with them. Now you can understand why government might not have prioritised that in a world where the budget constraint is binding, but in a world, where all of a sudden, the budget constraint is no longer binding, you would really have hoped that there'd been a much greater focus on those long-term things.

I'm quite confident, because I know the people who have done this work, that governments — and I say this, both Commonwealth and State — have received that advice. You can see it overseas. Look at the difference in the composition of our fiscal response and of that of some of the Europeans, where the Germans alone have put a massive amount of money in to accelerate the transition to a more hydrogen-based economy. They've really focused on how — and not just Germans, Europeans more generally — they've really focused on how do to actually position themselves better to succeed in a low-emissions world as we come out of this.

Who knows who wins the US presidency? But Biden's been quite clear: if he were to win, he'd be drawing on elements, similar elements. And in a way, we look like the odd one out in that we haven't done much in that space. It is not the case we haven't done anything. We have, because we've put a little money into the technology roadmap, and we've put some sensible investment into improving the transmission links. But we could have done a lot more and positioned ourselves a lot better. But to do that, you would have had to have changed your language, your narrative about coal. You would have had to change your narrative about when are we going to aim for net zero by, insert what year you want.

Prof Schultz: Okay, thank you. Anne, two things, you might want to respond to what Martin's just said and then come back to your disappointments, or the other way around.

Prof Tiernan: My disappointments would be not dissimilar to the line of questioning that you've pursued with Martin, really, Julianne — the personalisation and narrowing of the advisory arrangements. The National COVID-19 Commission is one example, the limited thought diversity of the people who were drawn into these different commissions and task forces is an issue. Then, the stubborn resistance to contestability or scrutiny and accountability of those bodies. Martin has understandable confidence in the capacity of the APS, as I do too. but I think it would have been really nice to have some lived experience from people in lots of different places instead of people suddenly being surprised that aged-care homes were really vulnerable and in shocking shape. The only person who didn't seem to know that was the minister at Senate estimates when he got

asked about it. There are a bunch of vulnerabilities that everybody knew were problems. What's disappointing is the extent to which it's been impenetrable.

Martin points rightly to the lack of effective demand for advice that's not consistent with preferred ways forward. That there is so little in these stimulus and support programs for women, I think, it is scandalous, and similarly for young people. I'm not as good natured as Martin is, and I really agree about the extraordinary way the higher education sector has been dealt with. If you're actually serious about setting up the country for knowledge and skills, and other opportunities that might exist at the place level to create prosperity in lots of different parts of the country that haven't enjoyed it over the last period of time, then those are very short-sighted strategies.

There is something about the architecture of our advisory arrangements and how vulnerable they are to the whims of political leaders of whatever colour, to filter out anything they don't want to hear. I think, to some extent, the success of the public health response might be masking some of those problems. There's a lot of goodwill to go around at the moment, but there are real questions to be asked as we get to March when the stimulus support is planned to stop.

I suppose my other disappointment is the extent to which we have accepted these tropes of: people have lost their jobs, through no fault of their, presumably people previously lost their jobs through some fault of theirs. I think there's a bunch of things that I still don't like in the discourse that I think will come to a head if we get to March and there's an attempt to put Jobseeker back to where it was at the Newstart level, which is just wholly inadequate. There are a whole

bunch of other questions about very fragmented, damaged delivery systems, aged care just being one of the most spectacular. What will be the ways in which those will be dealt with? Will it be similarly piecemeal? That is my concern.

Prof Schultz: There's a strong contrast, isn't there? If we're thinking about being forward looking, the importance of the education sector is obviously crucial. And there's a very strong contrast, I think, between the resources, the capacity and so on that have been thrown at the health system and the medical research community, by contrast with the support for the higher education sector. I'm just interested to try and understand this. I'm sure everyone in this room is dealing with this one way or another, in terms of the cuts to the universities, the huge numbers of people that we are seeing lose their jobs, the lack of opportunities for young academics, as well as the increased costs for young students. I'm interested in how important and how damaging you think that targeting of education has been in terms of creating a new future, for creating a new normal. What do you think the consequences of it might be? And I guess in a way, maybe you have some insights into where it's come from?

Dr Parkinson: If I've got any insights, they'll stay with me. But, look, I think there was a view in parts of the political process and in parts of the business community that universities — and I'm not saying this is right, but there is a view — were fat and complacent, that they had big reserves, they were profligate and they indulged in a whole pile of "research," in inverted commas, that was going to do nothing about helping Australia's future.

And to be frank, I suspect that part of the response has been opportunistic, that's because of the departure of international students, this is a chance to put the screws on the universities and force them to actually engage more with business, force them to get more efficient.

I don't actually disagree that much of the university sector is inefficient. I also don't disagree with the argument that the university sector has taken on a lot of risk with the way it's come to rely on international students and particularly international students from China. My response is that under both Coalition and Labor governments, these were the incentives that governments put in place for universities to respond to.

And, yes, you [the government] don't like the outcome. Well, congratulate the universities for acting rationally in response to the incentives you put there. If you didn't like that outcome, you should not have put those incentives there. And please don't tell us that you didn't know this was the obvious outcome because you've been told, and you've been told time and time again.

The flip side is, I think the university sector is absolutely, utterly hopeless at engaging with government as a sector. Not individual universities, some are very good, but, as a sector, it's hopeless in engaging with government. The university sector has an incredible sense of entitlement. And frankly, there have been parts of the universities which have looked down their nose on engaging with business because that's all a bit dirty and beneath them. I think one of the things that will come out of this is that we have imperilled a \$38-billion-a-year export industry, our third largest. That has been imperilled. I can't undo what's been done there. What I can do as a chancellor

is work with vice chancellors and other chancellors, and people like my dean, Eric Knight here, to try and drive better engagement with government, so government has a better appreciation of what universities are actually doing, a better appreciation in the community, and better appreciation and engagement with business and community groups.

Prof Schultz: Anne, you're very involved in that business engagement through Griffith University. What's your take on all of this?

Prof Tiernan: Look, I really agree with Martin on both sides of that debate. I don't think universities have always been very good at doing those kinds of things. And I think the other thing I point to, Julianne, is that the federal government has seemed incredibly surprised that it was in charge of higher education policy and has shaped these incentives and outcomes in lots of ways. But I think that state governments have been a bit missing in action, too.

As we all know, there's no real policy home for thinking about the universities as platforms for economic activity. I mean in terms of their sheer size, resources, capability, what big employers they are, what big purchasers they are. I work in the engagement space at a university that was set up to be an engaged one and has a proud tradition of doing that, but at times the times didn't suit us. That seemed like not where we needed to be heading. I'm pleased that we stayed the course at Griffith. But I don't know that state governments and the universities and local governments, frankly, have thought enough about the ways in which, if they align their procurement, if they thought about their local workforce strategies, they could come together as anchor institutions to really shape some fan-

tastic outcomes. That's a lot of the work that we're interested in doing. I know a number of other Australian universities are interested in doing that, too.

That seems to be understood by local federal MPs. The unis have to get better at communicating that. I'm really worried about the loss of talent in the very precarious early years of academic careers, of what will happen to talented young researchers. The volume of those that will be lost in the period ahead is quite tragic. And you can't just flick the switch and bring those kinds of careers back, unfortunately.

Dr Parkinson: Can I just add to that? Look, I agree totally with Anne, that's where the big risk is. The one thing is, the sector has got to stop complaining about the situation we're in. We're in it, we can't undo that, so now we've got to make the very best of it, and that means actually stepping up and doing things and being more innovative and taking risks and moving out of our comfort zone. In that respect, we're no different to any other part of the community in the way we're going to have to respond to this new environment.

Prof Schultz: It's very interesting because I'm sure you're both right in your analysis, I don't quibble with it at all, but it does strike me that there is something particular about education, as indeed with the cultural sector that we've been talking about. Education — whatever the inefficiencies and arrogance and what have you of individual universities or universities as a group — they have objectively succeeded. The incentives they were given as the funding was reduced, they responded to rationally, created a market, as have so many other sectors. Our export market has grown primarily with China across all sectors of Australian industry, the universities have

responded in that same way, they've made a business. Similarly in the creative and cultural areas, people have made businesses. They've made businesses which have been quite successful and have sustained the sector. What I think has taken people, both in education and in the cultural space, by surprise is that at the base of both education and culture is a purpose. The purpose is about building capacity, it's about creating meaning; they are both about making meaning which is also an economic activity.

It is particularly striking that the two sectors which have been most directly affected by political decisions in this round have been the ones which have been in that space of making meaning and having a clear public purpose. Reflecting back on what Peter Hobbins was saying this morning, about the Sydney University professors in the early days walking around the city, and finding the treatments or ways of dealing with the early pandemics and diseases in the colonies, the university professor was a sort of adjunct of the purpose of the state.

And what we are now seeing in both of these areas is somehow that that purpose bit of education has been cut off or ignored. It is as though they have been punished for being successful in the financial and economic space, and the purpose of education to increase human capacity has been lost sight of. I don't know, it's just an observation.

Dr Parkinson: I think it's actually a good observation. I won't talk about the creative sectors, but I think the universities in part lost sight of their role of purpose and stopped articulating. I think there's a presumption — and I'll be blunt — “don't you know how important my work is? Therefore, the Australian taxpayer should fund me.”

Well, actually, there is a person who is sitting at Mount Druitt earning minimum wage and living in crappy housing, so why should I as a politician prioritise giving money to you, an academic, when I could equally be giving it to improve their health, their education or their housing experience?

Prof Schultz: But we're not in a zero-sum game anymore.

Dr Parkinson: Well, no, no, no. But we —

Prof Tiernan: I was going to say, they didn't really do that either, Martin.

Dr Parkinson: No, no, no. I'm not saying that is the way they've thought about it. But if we want to win that argument, we've actually got to get back out there and explain the purpose. And saying our purpose is to educate people to go into jobs, well, no, that's only an element of it. Our purpose is to educate people to be good citizens, yes. But at some point, there's got to be an economic dimension to it. So how do you actually think about those economic dimensions? And that's got to come back to engagement of the academy with business. Now, I think the medical research side of the higher education sector has done that so much better than other parts of the universities.

And interestingly, you don't see that degree of tension when it comes to funding medical research, but you do see it when it comes to other areas. And the more you go into the humanities space, that tension becomes sharper and sharper. And I think that is because it has become almost fashionable for both ends of this debate to sit there and throw rocks at one another and not try and find a common ground. It's too easy. The two camps are entrenched. Coming out and trying to find middle ground requires effort, and neither side has been willing to do it.

Prof Schultz: I want to say something but, Anne, I'll let you go first.

Prof Tiernan: Well, I was going to say, I'm always sort of bemused. I don't disagree with Martin, that I think universities need to work harder to articulate their purpose. And I think you don't see the kinds of collaboration that, say, joint appointments or embedded activity that the medical research and training sort of allows in other parts of the universities.

But I must say, a lot of the culture war against universities is framed through the student politics experience of the very narrow group of people in parliament, or in cabinet, who tell these stories of the great wars they fought on campuses. That's not the reality at my university. Students don't have time to be doing that stuff. That was a luxury that the hyper-partisans were learning so that they could progress through the ministerial staff system to become ministers themselves. It's just deluded that that's what's happening on university campuses. But it is a very entrenched view and not — when we were framing this session, one of the things we didn't want to do was admire the problem too much. It absolutely is a problem. It is really incumbent on all of us to sort of see if we can find a way past it to articulating purpose.

I think that is a massive opportunity. What we're seeing now, in terms of the public health capacity, in terms of the testing regimes and capacity, is all about partnerships that were forged between government, business, the health systems over a long period of time. Every crisis this country has ever had where we found a solution and a way out of it was multi-sectoral in its response. If we're talking about post-war reconstruction, or we're talking about

modernising Australia through the 1980s and '90s economic reform, academics and researchers were really important players. As were business and other players in politics and the public service. This is why I'm so worried about the narrowing of these advisory structures, because it's just too selective and you can filter out anybody you don't want to hear. And that's evident in the packages that we can see.

Prof Schultz: It is interesting when you think back to the sort of founding principles that guided the growth of the universities. It was about the nation being more than a firm, you know, so it was about building the capacity across the board. When you talk, for instance, of the family at Mount Druitt struggling to hold body and soul together, the data show that people in those households, their aspiration for their kids not to stay there, they want them get opportunities to get an education that opens other doors for them.

You see that in the surveys that are done of the mining communities in Central Queensland, that they don't actually want their kids to be working in the mining industry. They don't see that as something that's got a long-term future. They want the pathways that broaden out. I think that that the sort of polarity that has developed between good doctors and bad humanities people, which we're all sort of vaguely aware of shapes some of these responses. Of course, doctors are good. That's why they take a Hippocratic oath. They can save us. They have the power of life and death. It is the unique proposition that attaches to medicine. So it sits on its own pedestal.

The notion that by drawing on the resources of history, of philosophy, of religion, of studies of the humanities and

social sciences we might actually inform the richness of the human response. There is a perception that somehow or other that is of less value in the sustaining of human life. In the short-term, of course, the medical knowledge comes first. You are going to give me the drugs that will save me. The longer term, that is probably not sufficient. It's going to be that extra thing that's going to make the difference.

Dr Parkinson: I don't disagree at all. And I think Anne touched on a key part of the problem, which is — and I'm on the public record, I've said this before — I think our political class has been narrowed. Just look at the experience set of people now. Compare them back to, say, the Hawke government of 1983, or go back even further and just see the more disparate sets of experiences. Too often now, kids go to university, they play university politics. And what do we know about that? It's the old Henry Kissinger thing. The reason why it's so vicious is because the stakes are so small. They learn winner-take-all approaches and they parlay that into a junior adviser's job or electorate officer job, and they become an adviser or senior adviser, and they parlay that eventually into some sort of pathway. They might have a few other steps out in, typically a law firm or some government relations, or, on the Labor side, they've gone into the unions. Then they come back. But they've learnt a set of behaviours when they were more formative, which they then carry through into national politics.

The other thing I'd say is that what we've seen in the last 15 years or so has been the injection of behaviours that have been, unfortunately, have become more common in state politics in Australia into the federal scene. And those two things are, I think,

quite corrosive for us. But anyway, while it's interesting, we're digressing.

Prof Schultz: But that does raise the question, in terms of thinking about where the new opportunities might lie. If this is a genuinely transformative moment, like the Great Depression or like the end of the Second World War, if you were trying to think, well, what are the opportunities, how might you go about imagining a restructuring, a reshaping, where do you want to be? A couple of questions. One, what might that look like? But a prior question in a way is, where would you begin to have that conversation apart from here? Anne?

Prof Tiernan: Well, there's been a bit of talk about the federation and how well or otherwise the federation has performed in the crisis. I think there's a whole series of questions that relate to decentralisation, devolution of responsibility, recognition of the subsidiarity principle. What we know is that Australia is diverse and becoming more diverse and to accommodate that diversity and difference was why we've got the design that we've got.

But we need to find ways of tapping local knowledge and insight in the way that the pandemic has revealed we need to do. We need to normalise and institutionalise that. And that's pushing against 30 years of centralisation backed up by the vertical fiscal imbalance between the states. One of the things, Julianne, that we haven't had a chance to talk about is the role of essential workers in this crisis, and how the roles of people doing that really important work need to be valued.

Now, these are the people who work for state and local governments and often who are performing those kinds of roles, and there are frontline roles in the federal

government too, of course. I think there is something about getting power and responsibility and opportunity and capacity out into the different and diverse parts of the country. And that will take be a big shift of habits and cultures. I think people can see that their community, how things have been organised, that this level has been really important. How do we sustain that? What are the mechanisms we can put in place to sustain that rather than going back to business as usual? And we haven't got time to kind of talk about the national cabinet and what might be good about that, but also what might be weakening about that as well.

I think it's all about subsidiarity, non-absorption, putting things back out and keeping these communities, and their willingness to be co-producers. We talked about data and insight about what's going on, on the ground and being able to match those things up in terms of local action. Everywhere that the pandemic is being handled badly there has not been enough local capacity. There was too much trying to be done from the centre, as in the UK, which is the classic example. We need to think about the partnerships that exist in different places to accommodate the very different needs that have been exposed and have probably been there all along.

Dr Parkinson: Just to add to that, the data that's available and the technology now allows you to move away from one-size-fits-all approaches. And if we're really serious — people have talked about it for years — let's embrace, citizen-centric design. Well, if we're really serious about it, we've now got the data, we've got the technology, to deliver it. And the circumstances are sufficiently different geographically and across different cultural groups, across different

socioeconomic groups that we should actually start putting much more emphasis on pilots and fail fast. Have a go, fail fast. The problem is, our whole culture in Australia is, if you fail, then forever you've got a big black mark on your forehead. Contrast that to the US: as an entrepreneur, if you fail, if you try something and you fail and then you try something again, the first thing people ask is what did you learn from your failure? Whereas in Australia the response is, well, why would we? You failed once. Why would we want to back a loser? That cultural dimension is pretty important.

Prof Schultz: I think you're absolutely right, but the other side of that is that we have perpetual trials. We have short-term grants. We have the systems that — things that are put out but not followed through. People do something, they get it up, they do it. They do not get it to a sustainable practice, but they get it to the point where it is almost ready to go and it stops, and then nothing: it disappears. A few years later someone will say, let's do a trial in this area again. I mean, I, in my own experience, can probably count a couple of dozen examples where that's happened, where things have been done as a trial, and then closed down and then come back again as another trial.

Prof Tiernan: Yeah, I really agree with that, Julianne.

Prof Schultz: They haven't failed, but they've never gone anywhere, not be implemented to the point of sustainability.

Dr Parkinson: I couldn't agree more. And that's particularly acute in Indigenous affairs. The flipside, though, is the experience of NDIS. The National Disability Insurance Scheme was set up in a series of trials. Geographic areas were going to do

different things. We were going to learn. We were going to make sure that, because we'd absorb those lessons and then we'd roll it out, that it would work much better.

What happened? As we started, people here were saying, hang on, that person there is getting something I'm not getting, that's not fair. The political class put on pressure to abandon the trials, abandon the "let's learn where the problems are going to come from" approach and jump immediately to trying to offer it to everybody. That's fine if you can actually provide the supply. But part of what the trial was about was how do you actually build the supply of resources and facilities to match what will be the growing demand? And so, again, as citizens, our impatience and our sense of equity was being insulted —

Prof Schultz: And a noisy public response.

Dr Parkinson: A noisy public response.

Prof Schultz: A noisy and ill-informed public response.

Dr Parkinson: Yeah, exactly. But so much of what happens now is politicians hear the megaphone, but they don't know how many people are yelling into the megaphone. And more often than not, it's a very small number of people who are yelling into that megaphone. And so they politicians are responding to social media.

If you look in the climate-change space, the proportion of people who really, utterly disbelieve the science, as an absolute you'll never be able to change their mind about anything, is minuscule. I mean, it might get to 10 percent of the population. But they're disproportionately influential in the media and in particular parts of the media, which are influential with the political —

Prof Schultz: In our very shrunken media.

Dr Parkinson: Shrunken media.

Prof Schultz: Anne, you wanted to say something?

Prof Tiernan: Yes, I really agree with that. There are these tensions between the expectation of universality and sameness and equity and accommodating different requirements in place. But I'm really interested in the potential to be aggregating capacity and resources at the place level, or closer to where people are from the different sectors. I always get really frustrated when — it doesn't matter what tier of government it is — they decide to open a new office with a boundary that overlaps somebody else's but doesn't align. I actually think there's a lot of scope, and maybe this is a role for universities, Martin, in terms of thinking about aggregating local capacity as a platform from which to do a variety of things, of a shared information base with a good understanding of the local context and trying to build local capacity to do that.

What I'm worried about is that there are these cycles of fashions of — it'll be all about the place, or it'll be all about this or that. And then there'll be turnover and churn and the institutional memory of what's happened before will be gone and there's no history. And people will want to start again. I think it's really incumbent on citizens and people who have thought quite hard about the experience and what the pandemic has taught them, to be thinking about demanding these kinds of things from decision-makers. We've got a lot of unfinished business, don't we, in terms of reforming the constitution, local government recognition, the Uluru Statement. There's the republic debate that many people are kind of keen to reanimate. There's a whole bunch of issues that that we need to talk about as a nation. What's the catalytic opportunity to do that

in a way that isn't divisive, that is inclusive and doesn't break up into the usual camps?

Dr Parkinson: Can I just back that in? I think one of the great things about the changes in the Closing the Gap strategy has been the emphasis on place. We've been trying to edge up to that and localised data and people on the ground being able to actually play a key role in determining what needs to be done is absolutely central.

But if we come back to the question of COVID and its impact more broadly, one of the things that's really interesting — and to me it's a two-edged sword — is the whole phenomenon of working from home.

Working from home could have some real benefits. It's about localism. It's about strengthening community. You live, you work, you participate in the community. You have your children educated, whatever, all in a geographically constrained area. That could be really good for mental health and social cohesion and a whole variety of things. But the social cohesion could well be at a micro level and the macro social cohesion could be eroded because I am spending more and more time with the people I have nearby — I've self-selected into a place where everybody who is there looks like me.

Equally, if you think about working from home, there is going to be some really big implications for how we do housing design, how we think about the risk shift and the cost shift. The risk shift is the OH&S risk, which is now sitting at home with you. The cost shift is the electricity and heating and the like, that the employer used to provide, it's sitting at home with you. What does that then say in terms of compensation arrangements?

Prof Tiernan: The care shift.

Dr Parkinson: And then there's the other thing: does working from home simply mean that women end up taking on even more of the domestic duties than they do now? The other thing in all of this is to remember that working from home is a white-collar phenomenon. It might impact on all of us and it could be advantageous, or it could be disadvantageous, but if I'm a blue-collar worker or if I'm in the personal services sector, I've still got to go to the building site or the factory or the café or wherever. I'm not getting the benefit of that. And so it's not to me the panacea people are presenting it as.

Prof Schultz: Did you want to add something, Anne?

Prof Tiernan: No, no, I was just really agreeing that I think that's right. And I think there's a lot of potentially stranded assets, too, in CBDs and built-up areas. I think there's a lot of concern about that as well.

Prof Schultz: We're going to take some questions?

Prof Knight: I think we've come to time, so maybe —

Prof Schultz: Oh, sorry. I thought you wanted me to go on and then —

Prof Knight: No, no, that's fine. Pass around the conversation on the panel.

Prof Schultz: Okay. What will we do as our last topic? We have many left here. I think that one of the things, just pulling together a couple of the comments that you were making earlier. I think we've all got good reason to feel quite proud of the way Australia has responded to this. The way individual citizens have responded and how we responded as a community, it's actually been an exemplary set of behaviours over a trying time.

And so that level of trust in government, public services and expertise is quite high.

The question is how that higher level of trust can be maintained and built on to create something better in what is going to be a very volatile global environment. We're looking at a situation with China where it looks like Australia could well be the demonstration project of China's power.

Who knows what's going to happen in the US with the outcome of the election there? Europe's very fragile. Britain is no longer able to provide us with meaningful guidance.

We've demonstrated that the community is resilient, that it has got trust, it's got capacity and is willing to actually take that extra step. How do we play that out in a global environment where our normal sources of guidance and advice are not really looking like places you want to take a lot of guidance and advice from and where it is much more volatile. And that's before we add in climate change and the other things which are going to be profoundly destabilising. How do you see this playing out in that global context? We've got some good opportunities. But how do we measure it?

Dr Parkinson: Yes, this is one of those things where I think we and a handful of other countries have the opportunity to improve perceptions of our domestic operations, if you will, because of the way in which we've handled the virus. And I think in terms of Korea, Taiwan, Japan, Singapore, New Zealand, Australia, and the Asia Pacific looks like a blip compared to the failures of Europe and the United States.

There are two things we have to think about. One, internationally, is any coordination on challenges of the global commons is going to be harder going forward than it has been in the past. You started off with the questions of what excited, surprised and what disappointed us. What I should

have said in the disappointed space is this is the first crisis I have seen in my lifetime where there has not been some attempt at a coordinated or, if not coordinated, at least collaborative, global response. Think about SARS, MERS, H1N1, think about Ebola, think about the GFC and the role that we probably glossed up a bit on Australia's role, but we played a pretty important role.

Think about the G7 and the role it played — go back to the recessions of decades earlier. Yet there's been no international response. Yes, scientists have worked together. Medical researchers have worked together. Businesses have worked together. But nations have not. And that's a reflection of two things. One, the United States not being prepared any longer to pay the price of global leadership or global coordination. It created the system and it no longer believes in, or at least its current leadership no longer believes that it is getting a fair return from that investment. And then you've got a China which is unwilling to lead, is incapable of leading. Then you've got a whole pile of other players who are big enough to be disruptive but not big enough to step in and replace that US coordination role.

I think the multilateral system — and I've said this elsewhere, and here I'm really channelling my friend Alan Gynge — the international order is no longer under threat. The international order is gone. It's destroyed. And the question is, how is that going to constrain Australia's ability to take decisions around trade, economic investment decisions, migration decisions, foreign investment policy, national security? We are going to be in a world where this is the most contested part of the world and we are going to spend more on national security. And to the extent that we are going into this with

much higher debt, that is going to put real pressure on our ability to spend in other areas.

The second thing, coming back to domestic issues, is economists love to talk the concept of creative destruction. One of the things that happens in a recession is you wipe out a lot of inefficient firms and, in your classical economics model, those workers immediately transform into other jobs that have magically appeared. We know the world doesn't work like that. Never did. You run the risk of, as you withdraw either the stimulus or Jobkeeper, throwing people onto the scrapheap too early if the economy has not yet picked up enough to be able to begin to generate jobs that will absorb those people.

How we navigate that and the tension of having to wind back fiscal stimulus is going to be really, really difficult. The one thing is there is no inflation on the horizon. I can't see in the foreseeable future — and by that, I mean many, many years — where inflation is a problem. So, it does allow the central banks globally to focus on keeping interest rates low. And that means that we can fund the fiscal stimulus that's been injected globally. But what it does mean is that we are going to need to find new instruments. And, where there are pockets of pressures emerging, we're going to have to rely much more on regulatory and particularly macroprudential instruments. And that has not been a space in which we have been particularly comfortable historically. So, I think they're two interesting perspectives.

Prof Schultz: Anne?

Prof Tiernan: I really agree with all of that, but, you know, at the same time, we've totally divested our investment in our diplomatic capacities, so we're carrying big

diplomatic deficits. That doesn't seem like a very smart thing to have done in terms of a time that's so dangerous and difficult and requires really good insight.

I think the opportunity of the climate transition, the transition to low carbon is one that is being embraced even in the absence of any coherent national policy leadership. And poor Martin has had to endure having done all that proactive work and having things in place, only to have them dismantled through the political cycle.

I think we'll see a lot more subnational collaboration around some of that stuff. The New South Wales government is doing some really aggressive work on decarbonising the economy. I think everybody's wishing the Queensland government would do that — particularly in light of the Deloitte report that came up on Monday (Philip, 2020) that showed that 70 per cent of the new jobs will be created here — or otherwise it'll just be a complete disaster. I think the way policy gets catalysed and the way some of these shifts are made will be a lot less centred than they have been in the past. They'll have to be, because we can't endure another wasted decade, it's just too dangerous.

One hopes that the capabilities around smart regulation, or some of these other skills that we haven't necessarily maintained, can be activated quickly. But, there's a number of areas of policy where we may not have what we need and so how do governments partner with other sectors in order to get where we need to go? And citizens just really need to be making that demand.

On the social cohesion front, Martin, while you were talking about the generational divides, some of the reports we're seeing of how pessimistic young people are about their prospects are really very concerning. I would hope that, just as Australia was a democratic innovator back at the turn of the last century, we might be able to leverage off that history and energy. We might be able to kind of get off our humility wagon and hold ourselves up as a bit of a beacon. But we'd have to hold ourselves to some high standards.

I do think the fundamentals are there, and the holding centre of Australian politics has been clear. Unemployment will really strain that. And particularly in parts of regional Australia, where it's not implausible that right-wing extremist groups and other groups become very disenfranchised. And it doesn't take that many. The Scanlon survey (Markus, 2020) is showing at least some of that already, even if it is modest it doesn't take much to grow. People need to feel like they've got a stake and need to be involved. And that's what this country always did so well. That it seems to me, is the big policy opportunity.

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After COVID-19: Creating the best of times from the worst of times: Rapporteur's summary

The Royal Society of New South Wales and Four Academies Forum
Government House, Sydney
5 November 2020

Professor Eric Knight

Executive Dean, Macquarie Business School

Email: eric.knight@mq.edu.au

Abstract

The Royal Society of New South Wales, with the Four Academies, held the Forum “After COVID-19: Creating the Best of Times from the Worst of Times” on 5 November 2020, live streamed from Government House, Sydney. The Forum examined how the COVID-19 pandemic has become a wake-up call for all of us to drive a wide-ranging, national program that will create a more resilient, self-sufficient and prosperous Australia. This paper is a summary of the day's proceedings, that draws on the verbatim record of the Rapporteur's summing-up on the day, modified as appropriate, for inclusion in the *Journal & Proceedings of the Royal Society of New South Wales*.

Introduction

Thank you very much to the panellists. It falls to me to close the proceedings with thanks to Her Excellency and the Royal Society for organising the Forum and in particular to Susan Pond as the chair of the programme committee, who takes the credit for today's event.

This is something of a fraught task for me as I am a student of Professor Duncan Ivison, who was my former boss at Sydney University, as Deputy Vice Chancellor of Research. He was a master of being the rapporteur and summarising, but maybe the way to finish is to go back to how we started.

I think if we reflect on this particular annual forum of the Royal Society and the Four Academies in future years, it will be worth knowing that it occurs in the shadow of two significant events: one being COVID,

both here and globally; and the second, amidst a US presidential election where the result is not fully clear. I think that was palpable when we came into the room today. It is still yet unclear how both of these events will unfold. These things hang over today's forum, though it was implicit throughout today. Dr Peter Hobbins made a small reference to it when he referenced 1776 and the significance of that date: both the Declaration of Independence but also the year Edward Gibbon published the first volume of the *Decline & Fall of the Roman Empire*. His reference there was to *Ouroboros*, that ancient symbol which brings the God of Life, Death and Reincarnation together.

Omnia quærite

So, with that context in mind, how do we approach this as the Royal Society? Well, perhaps motivated by its founding motto

“omnia quærite,” question everything. A motto inspired by enlightenment philosophy, scientific method, progressivism, some notion of humility and hypothesis in how we venture into the world. It was in this spirit that both Professor Ian Sloan opened today but also Her Excellency the Honourable Margaret Beazley motivated this year's forum with the question “how do we build back better”?

Rather than summarise all of today's sessions one by one, perhaps I can have a go at thinking about that question of how we build back better by piecing together the building blocks. Let me think about this in terms of three blocks: a kind of inverse pyramid, if you will, from the largest number of people involved to the smallest number of people involved.

The Community

The largest building block might be how we think about community. Dr Martin Parkinson talked about the global commons, and community is both international and national. Dr Peter Hobbins, in his keynote address, helped us think about community in historical terms. The kind of community we have been, the kind of positivism and progressivism that motivated 19th Century idealism in this country and the bringing of Commonwealth traditions to this country. Anderson Stuart, who left Edinburgh to become the founding Professor of Medicine and Dean of Medicine at the University of Sydney, when facing a pandemic or an epidemic, realised a community apathy towards immunisation and so Dr Peter Hobbins' charge was, “Are we immune to history? Do we learn from history?” Do we follow the virtuous cycles that he saw in the aviation industry, where we improve

on what has happened before? Or do we somehow build up some immunity which resists us from learning?

Community can also be considered in the sense of local communities. The regional communities and hard-hit communities that Distinguished Professor Larissa Behrendt talked about in “The Weaving Power of Indigenous Storytelling” such as the Oak Valley Indigenous communities who are seeking to close the gap on life expectancy and poverty. From Distinguished Professor Larissa Behrendt we heard both of the challenges but also of the pride and resilience from those who were beginning to find empowerment in that local decision making. This is something that Professor Anne Tiernan also touched on in her remarks on decentralized government, and Bethwyn Serow in her reflections on Australia's artistic community.

The State

Community is one way in which we are beginning to build back better. State is perhaps the second building block, a second organising principle for community, as in the national state but also state in the federal sense: New South Wales, Victoria, and others. State governance was a theme that came through in the second session on “Sweeping Changes to Australia's Healthcare System.” Dr Theresa Anderson and Professor Gregory Dore spoke to this. They described that governance process as “agile,” and I think that was a term that Distinguished Professor Larissa Behrendt also used. “Tiger teams,” “flying squads” and the pride of these teams coming together was how Theresa characterised the NSW response to COVID.

My own observation from this was not simply the process of agility but also the risk appetite. The risk appetite to determine when do we shut down and when do we leave things open? And it is on this that Theresa Anderson gave us some sense of the accountability that she has in mind. She referred to the notion of the needs of the individual and the needs of society coming together and informing those decisions. Risk appetite in some sense being a calculus: a calculus that is calibrated both within democracy but also in partnership with the premiers of state and here we find our state premiers finding their voice in different ways within the Commonwealth.

Now, I suppose in that session we were talking about governance and state in a health sense but in our last session, "Reshaping Australia's Institutions," we also talked about it more broadly in terms of economics. So, we can also reflect on how we organise state. How we build back better in the context of an adverse job market for our future generations, the gendered impact of workforce participation and how we begin to find the right balance in higher education and creative arts, and other parts of state organisation, or at least ways in which the state organises our community.

Here, Professor Julianne Schultz talked about "the making" sectors and how we co-create. I think this is a second approach to how we build back better, and how do we bring the state into the community.

The Individual

Finally, the third building block is the individual. Each of us — and how do we build ourselves back better? Here I am perhaps informed by some of the thinking that Dr Jordan Nguyen brought to us and also

that we had from Distinguished Professor Genevieve Bell. She referenced Arnold Van Gennep's "rites of passage." I am talking about sense making and liminal spaces, the ways in which we begin to reconceptualise our own sense of time, embodiment and identity amidst the pandemic and how we begin to form cultural practice out of that sense of self.

For me, this made me think about COVID-19 through the lens of Hippocratic corpus. This work raised the question "when do we know we are in a medical crisis?" If COVID puts us in a liminal zone, then when do we know it is also a pandemic crisis? When have we reached its peak? When is it at fever pitch?

The answer, from Gennep, might be: that depends on our own individual choices. In this respect, science is not immune from society. Instead science is a social force, and we must determine its limits. Science and technology can constrain us in the way that the pandemic and science has limited what we can do. But science also has the potential to enable what we can do and here I think Dr Jordan Nguyen's thinking about the ways in which technology can enable those who are disabled really comes to the fore. I am thinking about how we make sense of *ourselves* and our role amidst crisis to find new meaning. What Jordan was able to show was stories about the ways in which people who he worked with were able to find lives that they had reason to value for themselves and use technology as a force for good.

How we build back better

Where does this bring us? What is the answer to this question of how we build back better? Well perhaps in the spirit of Van Gennep and ambiguity and liminality — and indeed the

motto of the Royal Society of South Wales to question everything — maybe it's not about the answer so much as about the question. For, as Professor Greg Dore said to us, life will return and as Distinguished Professor Larissa Behrendt also said to us, stories do matter.

So I think if we were going to apply the kind of *ouroboros* philosophy to today's forum, if we're going to think about how we bring the end back to where we started, how we bring the individual back into the community, we have to ask ourselves the question: how do we build back better, not so much in society but also in self. How do we both seek to embody the history that is

come before us in how we act but also how do our actions of self enact the history that we want to see in the future?

So with that, I'd like to draw the 2020 annual Forum of the Royal Society and the Four Academies to a close, to welcome you to refreshments, and to think about how we build back better in society and self. Thank you.

Acknowledgements

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Thesis abstract

The making of smart cities: Borders, security and value in New Town Kolkata and Cape Town

Ilia Antenucci

Abstract of a thesis for a Doctorate of Philosophy submitted to Western Sydney University,
Australia

The making of smart cities transforms not only infrastructures and practices but also the techniques of urban government and security, and economic processes. This thesis draws on analysis conducted in two research sites: Cape Town, in South Africa and New Town Rajarhat, a satellite township on the outskirts of Kolkata, to present three key arguments. First, and as opposed to mainstream narratives that describe smart cities as seamlessly connected environments, this thesis suggests that urban digitalisation is linked to bordering processes. Whereas critical literature has comprehensively discussed the political implications and risks associated with smart city projects, such as corporatisation and technocratic governance, the specific relations between digital infrastructures and borders, within the urban space, have not yet been discussed. Secondly, this thesis argues that smart cities are inherently security projects, insofar as the deployment of a computing infrastructure of sensing initiates a pre-emptive apparatus. In security systems, such as the Emergency Policing and Incident Command (EPIC) program in Cape Town, or the Xpresso software for social media monitoring in New Town, algorithms are continuously modelling and acting upon future scenarios: from traffic

jams to wildfires, from crime hotspots to citizens' moods. My third argument is that the computing apparatus of security also serves as an infrastructure of value extraction. Recently, there has been much theorising and debate about security platforms' economic operations, but the situated modalities in which they extract value from the urban environment remain to be examined. Overall, this thesis points to the socio-spatial, governmental and economic relations that computing infrastructures are generating, or reconfiguring, in the urban environment. These relations articulate distinct processes, including the hierarchisation and control of the urban space, pre-emptive policies and extractive strategies. Critically analysing these processes allows the registration of the political implications of smart city projects.

Dr Ilia Antenucci
Institute of Culture and Society
Western Sydney University
Penrith NSW 2751
AUSTRALIA

E-mail: ilia.antenucci2@gmail.com

URL: <https://researchdirect.westernsydney.edu.au/islandora/object/uws%3A57684>

Thesis abstract

Auditory-motor entrainment: Behavioural and cerebral dynamics

Cécile J. Bouvet

Abstract of a thesis for a Doctorate of Philosophy submitted to Western Sydney University,
Australia

We often synchronise our movements to auditory rhythms in our environment without the intention to do so. Such coordination influences the stability of movement performance, and, therefore, can be used to our benefit in sport and therapeutic contexts. Research to date has largely reached a consensus about the mechanisms underlying intentional sensory-motor coordination, but spontaneous auditory-motor entrainment is still under exploration. This thesis addresses the dynamics of unintentional synchronisation towards various frequency relationships between periodic movement and auditory rhythm frequencies. It presents four complementary studies questioning the role of multiple metrical levels and their accentuation (relative salience) on the emergence and stability of simple vs. complex synchronisation in healthy adults. The first study confirms quantitatively the emergence of spontaneous synchronisation between periodic movement and auditory rhythms at frequency ratios different from 1:1. The second study introduces the benefit of a congruent accentuation pattern on the emergence of various frequency ratios. It leads to the observation that a ternary accentuation pattern facilitates synchronisation more than a binary accentuation pattern. The third study examines this new finding more extensively through the

recording of neural responses to various accented patterns using Electroencephalography, confirming a differential response to ternary and binary patterns linked to behavioural performance. The fourth and final study focuses on the benefit of accentuation patterns for the production of a more complex type of movement coordination: a multi-frequency bimanual coordination performance. This study also measured neural tracking of the accentuation pattern relative to the congruence of the motor coordination performed, showing that both sensory and motor systems influenced rhythm perception. All together, these results demonstrate that spontaneous auditory-motor entrainment can emerge at various frequency ratios in accordance with the predictions of the dynamical systems approach to action and perception. Furthermore, spontaneous auditory motor entrainment is modulated (i.e., increased or decreased) by the addition of simple accentuation patterns, depending on congruence with the auditory-motor frequency mode and the neural response to the accents. In addition, more complex multi-limb motor coordination performance responds similarly to accentuation, underpinned by auditory-motor coupling and sensory processing of the auditory rhythms. Therefore, the findings of this thesis open

new avenues for future research on spontaneous auditory-motor coordination and its application in the training and rehabilitation of motor performance.

Dr Cécile J. Bouvet
The MARCS Institute for Brain, Behaviour
and Development
Western Sydney University
Penrith NSW 2751
AUSTRALIA

E-mail: cecilebouvet@hotmail.fr

URL: <https://researchdirect.westernsydney.edu.au/islandora/object/uws%3A56254>

Thesis abstract

Hydraulic traits and drought mortality risk of tree species

Ximeng Li

Abstract of a thesis for a Doctorate of Philosophy submitted to Western Sydney University,
Australia

I ncreased drought frequency and severity associated with global climate change has contributed to large-scale forest dieback on all vegetated continents. Forest dieback may alter community composition, leading to cascading negative impacts on ecosystem function and service, and creating a positive feedback loop between biosphere and atmosphere. Traits-based approaches have emerged as a promising way to accurately predict the impacts of climate change on vegetation dynamics. Yet predicting the forest mortality pattern resulting from drought stress remains challenging, largely because of a lack of knowledge of the plant traits determining the risk and modulating the process of drought-induced mortality, and how these traits vary across and within species. Hydraulic traits define species distributions along local or regional gradients of water availability, and recent advances in modelling forest dynamics highlight the critical role of hydraulic traits in improving model predictive power with respect to mortality events. Using various ecologically and economically important tree species from New South Wales, Australia, my PhD thesis was designed to examine inter-specific variation of various hydraulic traits across a wide range of species native to five different vegetation types: Rainforest (*Acmena smithii*), Wet sclerophyll forest (*Eucalyptus grandis*, *E. viminalis*), Dry sclerophyll forest (*Angophora*

costata, *Corymbia gummifera*, *E. sideroxylon*), Grassy woodland (*E. blakelyi*, *E. macrorhyncha*, *E. melliodora*) and Semi-arid woodland (*Acacia aneura*, *E. largiflorens*, *E. populnea*). In addition, intra-specific variation of key hydraulic traits was examined for *Banksia serrata*. The primary objective of my work was to provide trait values that will help to predict the dynamics of tree species upon climate change with vegetation models. Furthermore, the correlative relationships among hydraulic traits and between traits and climate presented in this study broaden our understanding of plant hydraulic strategies and plant adaptation to low-rainfall environments.

Dr Ximeng Li
Hawkesbury Institute of the Environment
Western Sydney University
Penrith NSW 2751
AUSTRALIA

E-mail: liximeng2009@hotmail.com

URL: <https://researchdirect.westernsydney.edu.au/islandora/object/uws:54173/>

Royal Society of NSW Awards 2020

The Awards and Citations for 2020 were announced at the 1289th Ordinary General Meeting of the Society, held on Wednesday, 9 December 2020. These included the Cook Medal, which is the Society's highest honour, awards for research and scholarly excellence, and awards which recognise substantial service to the Society.

In 2021, nominations will be sought for the following:

- [James Cook Medal](#)
- [Clarke Medal and Memorial Lecture](#)
- [Edgeworth David Medal](#)
- [History and Philosophy of Science Medal](#)
- [Pollock Memorial Lecture](#)
- [Warren Prize](#)
- [Archibald Ollé Prize](#), and
- the [Royal Society of NSW Scholarships](#)

See the RSNSW web site for details.



James Cook Medal — Scientia Professor Richard Bryant AC

The winner of the James Cook Medal for 2020 is **Scientia Professor Richard Bryant AC FASSA FAA FAHMS** of UNSW (Sydney). Professor Bryant has made many seminal advances in the diagnosis, treatment, and identification of neural, genetic, and cognitive markers of post-traumatic psychopathology. His work has challenged the pre-existing notions of acute psychological response to trauma leading to major policy and practice shifts internationally in relation to how trauma survivors are managed. Professor Bryant has translated his findings into improving the mental health of communities throughout the Southern Hemisphere (as well as many trauma-affected countries in the northern hemisphere).

The Clarke Medal and Lecture — Distinguished Professor Michelle Leishman

The Clarke Medal 2020, in the field of Botany, has been awarded to **Distinguished Professor Michelle Leishman** of the Department of Biological Sciences at Macquarie University. Professor Leishman is internationally recognised for her work in plant ecology. In particular, her studies are directed towards understanding the success of invasive plant pathogens, vegetation responses and adaptation to climate change, plant conservation, and facilitating resilient urban green spaces. She has a number of active research programs which include development of a database for greening urban space, studying invasive plants and pathogens and climate vegetation response and adaptation to global climate change.

Edgeworth David Medal — Associate Professor Brett Hallam

The Edgeworth David Medal for 2020 has been awarded to **Associate Professor Brett Hallam** of the School of Photovoltaic and Renewable Energy Engineering at UNSW (Sydney). In less than six years from completion of his PhD, Scientia Fellow Brett Hallam has established himself as a national and international leader in the highly competitive field of crystalline silicon photovoltaics, particularly in the areas of light induced degradation, hydrogen passivation and defect engineering. Although he has made a major impact on photovoltaics globally, this is in addition to his profile and leadership in crystalline silicon photovoltaics in Australia. Professor Hallam's research addresses one of the key challenges in sustainability — that is, access to clean electricity. His work on hydrogen passivation to avoid light induced degradation of solar cells means that the cost of photovoltaics can be reduced greatly, increasing the competitiveness of this form of electricity compared with that generated by fossil fuels.

History and Philosophy of Science Medal — Professor Alison Bashford FRSN

The Medal for 2020 has been awarded to **Professor Alison Bashford FRSN FAHA FBA FRHistS**, an ARC Laureate Fellow from the Faculty of Arts and Social Sciences at UNSW (Sydney). Professor Bashford is one of Australia's most eminent historians, recognised internationally for her ground-breaking and transformative historical studies of the biomedical and environmental sciences. Her scholarly distinction is recognised by fellowships of both Australian and British academies. Professor Bashford has greatly enlarged and raised our understanding of past conceptions of race, population and place in Australia and the world. She has brought the history of the human and environmental sciences into the scope of world history. She has written five acclaimed books and numerous other published works in which she reveals connections of science and medicine with national projects and global ambitions. Further, her extensive and various studies have reoriented the history of science toward the southern hemisphere and the Pacific, showing us how natural knowledge has been assembled in Australia and the region.

Liversidge Lecture — Professor Richard Payne FRSN

The Liversidge Lecture for 2020 was awarded to **Professor Richard Payne FRSN FRACI FRSC** of the School of Chemistry of the University of Sydney. Professor Payne's research focusses on the development of technologies for the chemical synthesis of therapeutic peptides and proteins. These technologies have facilitated the preparation of numerous proteins bearing modifications that enhance activity and stability — critical features in the quest to develop efficacious protein therapeutics. His approaches have also been combined with recombinant methods to generate large therapeutic proteins and even antibodies — methods that have been widely adopted in the laboratories of international academics and pharmaceutical companies alike. He has developed synthetic proteins that are amongst the most potent antithrombotic agents ever reported, and which have an enormous therapeutic potential for thrombo-embolic disorders. Professor Payne has been awarded numerous prizes and medals including the 2014 RSNSW Edgeworth David Medal and the H G Smith and A J Birch Medals of the RACI.

Poggendorff Lectureship — Professor Angela Moles FRSN

Professor Angela Moles FRSN, of the School of Biological, Earth and Environmental Sciences of UNSW (Sydney), has been awarded the Poggendorff Lectureship for 2020. Professor Moles is an international leader in the field of large-scale evolutionary ecology. In particular, she studies the processes that shape global patterns and the way plants grow, reproduce, and interact with animals. She has a highly cited publication record, and the innovation and quality of her work has been recognised by numerous awards.

The Jak Kelly Award — Mr Matthew Donnelly

The winner of the Jak Kelly Award for 2020 is **Matthew Donnelly**, a PhD candidate at the University of NSW. Mr Donnelly is researching monolithic donor structures in silicon and their application in spin-based quantum computing, with a focus on using 3D fabrication techniques to precisely control tunnel rates and other parameters critical to the operation of spin qubits.

Warren Prize — Dr Simon Devitt

The Warren Prize of the Royal Society of NSW has been awarded to **Dr Simon Devitt** of the Centre for Quantum Software and Information at the University of Technology Sydney. The Prize, which was awarded for the first time in 2020, recognises research of national or international significance by engineers and technologists in their early to mid-careers. The judges were impressed with Dr Devitt's portfolio of achievements, including his publication in top-tier journals, and his activity in commercialising ideas in the realm of quantum computing through start-up companies. Dr Devitt, who completed his PhD in 2007 at the University of Melbourne, has held positions at the National Institute of Informatics, Ochanomizu University, Keio University and Riken in Japan, and has worked as research fellow for the ARC Centre of Excellence in Engineered Quantum Systems (EQUS) at Macquarie University. He has developed key quantum computing architectures in atom-optics, diamond and ion trap systems, and invented quantum communications designs, second and third-generation repeaters and the quantum sneakernet. Most recently, his work has focussed on the design of programming, compilation, and optimisation techniques for large-scale quantum technology.

Archibald Ollé Prize — The late Dr Ann Moyal

The 2020 Archibald Ollé Prize has been awarded to the late **Dr Ann Moyal AM FRSN** for the paper "P.A.M. Dirac and the Maverick Mathematician," *Journal & Proceedings of the Royal Society of New South Wales*, vol. 150, part 2, 2017, pp. 188–194. The paper's abstract: "Historian of science Ann Moyal recounts the story of a singular correspondence between the great British physicist, P. A. M. Dirac, at Cambridge, and J. E. Moyal, then a scientist from outside academia working at the de Havilland Aircraft Company in Britain (later an academic in Australia), on the question of a statistical basis for quantum mechanics. A David and Goliath saga, it marks a paradigmatic study in the history of quantum physics."

Royal Society of New South Wales Scholarships — Mr Sajad Razavi Bazaz, Mr Daniel Fox, and Ms Phillipa Specker

Mr Sajad Razavi Bazaz, PhD candidate at the University of Technology Sydney. In his PhD, Mr Razavi Bazaz studies the use of 3D printing for microfluidics. Microfluidics is a science which allows the manipulation of fluid samples, typically in the range of microlitres, within networks of channels ranging from tens to hundreds of micrometres. Microfluidic systems are becoming increasingly promising tools for the advancement of chemical and biological research with evident benefits. Today, 3D printing technologies have gained significant traction, being dubbed a third industrial revolution. Due to the expanding use of microfluidic systems in laboratories, 3D printing has emerged as an alternative method to traditional costly fabrication processes. Mr Razavi Bazaz has developed a new method for the fabrication of microfluidic devices and has validated it. He and his colleagues have established a start-up company to develop 3D-printed microfluidic devices for selective sperm selection for the IVF market.

Mr Daniel Fox, PhD candidate at the Australian National University. Mr Fox is studying the clinically important, but much neglected, human and foodborne pathogen, *B Cereus*, and has discovered that enterotoxins produced by this bacterium can activate cytosolic innate immune inflammasome sensors which mediate host defence against pathogens. The sensing of pathogens by inflammasome sensor proteins results in the assembly of the inflammasome complex. Mr Fox has identified a toxin NHE as a novel activator of the NLRP₃ inflammasome because it triggers formation of a lytic pore that promotes the efflux of potassium ions. He has also found it mediates the killing of cells from multiple lineages and hosts. It acts synergistically with another toxin secreted by the same organism, HBL.

Ms Phillipa Specker, PhD candidate at UNSW (Sydney). Ms Specker is investigating the role of emotional regulation in the management of post-traumatic stress disorder (PTSD) in refugees. Refugees represent one of the largest at-risk groups in the development of PTSD, with current treatments being much less efficacious compared to other trauma-exposed groups. Research suggests that emotion regulating strategies that refugees used to manage stress may be critically important in their recovery from PTSD. In the first part of her PhD program, she found that there were individual differences in the types of emotion regulation strategies that refugees used to manage stress and that those refugees who were better able to concurrently use cognitive reappraisal and emotional suppression had fewer PTSD symptoms. Currently, she is testing a novel experimental paradigm to investigate whether providing refugees with adaptive emotion regulation skills training will reduce PTSD symptomology and ultimately improve well-being.

Royal Society of NSW Medal — Emerita Professor Mary O’Kane AC FRSN

Emerita Professor Mary O’Kane AC FRSN FTSE Hon FIEAust was appointed as the first New South Wales Chief Scientist and Engineer in 2008 and remained in the position until 2018. Prior to that she was Vice-Chancellor and President of the University of Adelaide from

1996 to 2001. From 1994 to 1996 she was Deputy Vice-Chancellor (Research) and Professor of Electrical Engineering at the University of Adelaide. From 1989 to 1993 she was Dean of the Faculty of Information Sciences and Engineering at the University of Canberra.

Early on, as the New South Wales Chief Scientist and Engineer, she established a relationship between her office and the Royal Society of New South Wales which, in essence, provided the Society with access to the State Government. She was a strong supporter of the Society, providing funding for the publication of the *Journal and Proceedings*. Later she provided funding and hosted the Four Societies Lecture when it was the Royal Society's turn to organise this event. She also instigated an awards mechanism for the Society, by which the Science Deans of NSW and ACT universities came together under her chairmanship to make recommendations for the Society's prizes and scholarships. She advocated for the Society in government and also was a strong supporter of the Royal Society of New South Wales and Four Academies Forum held annually at Government House, Sydney.

Royal Society of NSW Citation — Emeritus Professor Heinrich Hora FRSN FAIP FInstP

Emeritus Professor Heinrich Hora, of UNSW (Sydney), has served the Royal Society of New South Wales with distinction over many years. Professor Hora is a former Vice-President and Councillor of the Society and is a current member of the Fellows and Members Assessment Committee, to which he has made significant contributions over several years. In that role, he has helped ensure that the most talented and qualified individuals across many fields join the ranks of the Fellowship of the Society. In addition to his extensive service to the Society, Professor Hora is a noted theoretical physicist who has made and continues to make significant contributions to solid state physics, the optical properties of plasma, and non-linear dynamics with the application of lasers to the production of nuclear fusion energy.

Archibald Liversidge: Imperial Science under the Southern Cross

Roy MacLeod

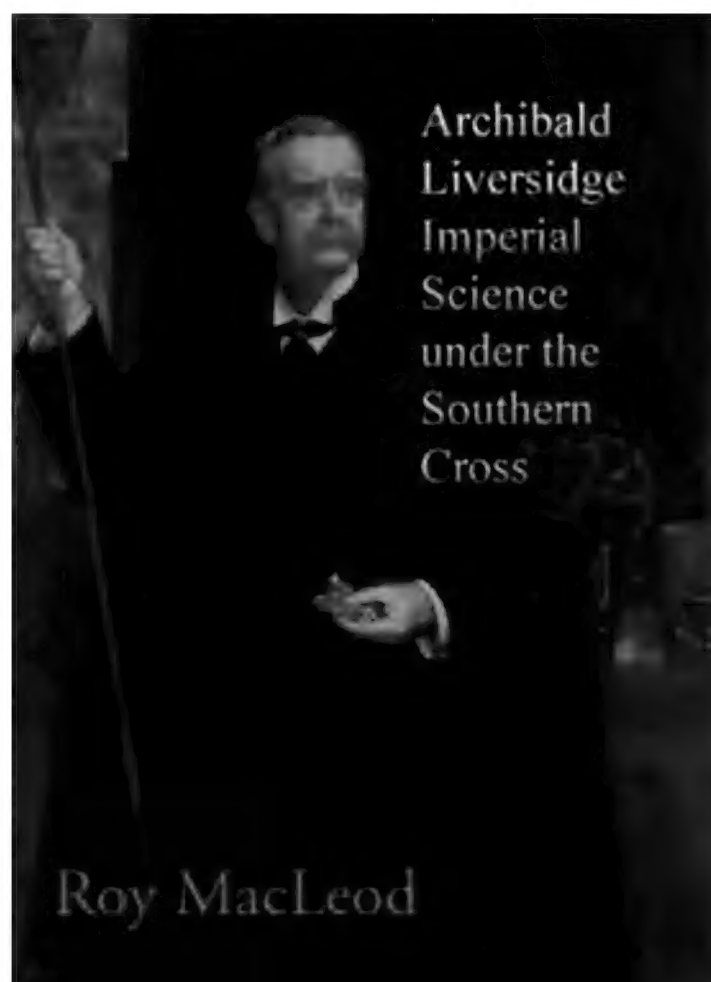
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When Archibald Liversidge first arrived at the University of Sydney in 1872 as Reader in Geology and Assistant in the Laboratory, he had about ten students and two rooms in the main building. In 1874, he became Professor of Geology and Mineralogy and by 1879 he had persuaded the University Senate to open a Faculty of Science. He became its first Dean in 1882.

In 1880, he visited Europe as a trustee of the Australian Museum and his report helped to establish the Industrial, Technological and Sanitary Museum which formed the basis of the present Powerhouse Museum's collection. Liversidge also played a major role in establishing the *Australasian Association for the Advancement of Science* which held its first congress in 1888.

This book is essential reading for those interested in the development of science in colonial Australia, particularly the fields of crystallography, mineral chemistry, chemical geology and strategic minerals policy.



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The Royal Society of New South Wales
P.O. Box 576
Crows Nest, NSW 1585, Australia



info@royalsoc.org.au (general)
 editor@royalsoc.org.au (editorial)
 www.royalsoc.org.au
 www.facebook.com/royalsoc

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